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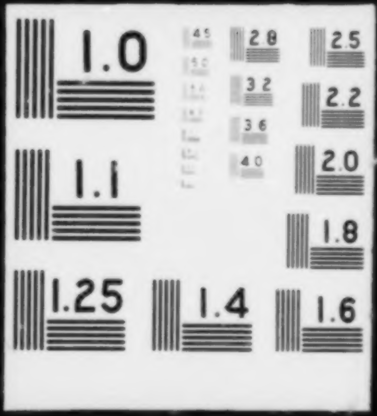
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16. Abstracts This report attempts to reveal the alternatives available to government and to private industry as they cope with the conflict of economic growth and pollution abatement. In relating the the multifaceted approaches to the problem, this report has two purposes: 1. To minimize the conflict between economic growth and pollution abatement by examining opportunities which are often overlooked; and 2. to create an information system which clearly identifies the empirical possibilities available within the pollution abatement strategies considered. This approach, which is called, Ecosystem of Machines Information System(EMIS), suggests a way of determining the minimum data needed by integrating data sets with abatement strategy; a way to maximize usefulinformation by collecting data in the context of its use, and a systematic way to judge alternative approaches for particular industries in a decentralized economy. Chapter 2 of this report outlines the design for the systematic identification of potential matches of industries, listing the basic computer routines. ~~In~~ chapter 3 a sample data base is indicated and processed through the alternative strategies for abatement. ~~Chapter 4~~ investigates the present practices of abatement policy and suggests opportunities through the EMIS method. ~~Chapter 5~~ Twelve outlines 12 reasons this approach will not work and 12 requirements which are raised by these objections.

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Mr. Paul H. Gerhardt
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Rockville, Maryland 20852

Re: Final Report, Contract #EHS 70-121

Dear Mr. Gerhardt:

In fulfillment of our contract we have prepared fifty copies of a final report entitled: "A Technique for a Systematic Identification of Pollution Reduction Measures: EMIS".

We would like to thank you and the others at NAPCA who were so helpful with their criticisms and suggestions. It has been a real pleasure to work with such committed and conscientious clients. We all sincerely hope this effort will be helpful as you pursue your mission for the public's health and welfare.

Sincerely yours,

Morton Gorden

Dr. Morton Gorden
President

November 10, 1970

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We would like to acknowledge the assistance of numerous staff members who have contributed to this report. The chemical analyses for identifying potential partners were done by Mrs. Marsha Gorden. The information systems design was done by Mr. John J. Golden, Jr. The HARCOR discussion was written by Mr. Charles N. Flinkstrom. "EMIS from the Firm's Viewpoint" was diagrammed by Mr. Russell A. Lovell, Jr. The production schedules were met by Mrs. Marjorie Ellis with the assistance of Miss Terry Daniels. Over-all project management and systems design was by Dr. Morton Gorden.

We wish to thank the many people who cheerfully criticized and augmented our work. While we are responsible for the errors herein, many people are responsible for the useful thoughts. People from industry and governments and the universities gave generously of their time and we appreciate their efforts.

Furthermore, we have been fortunate to have a client group at the National Air Pollution Control Administration which perceives the import of the Ecosystem of Machines Information System. We are grateful to our Project Officer, Mr. Paul Gerhardt, for the sympathetic understanding of our larger goals. We found that Mr. Ron Campbell's criticism and stimuli ultimately shaped the final report. Mr. Larry Barrett's efforts to bring us in contact with the informative people and sources were especially valuable.

Thus, while this report was the effort of six man-months of Development Sciences staff, it actually reflects the good will and time of a great number of cooperative people.

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A TECHNIQUE FOR THE SYSTEMATIC IDENTIFICATION OF POLLUTION REDUCTION MEASURES: EMIS

Chapter 1 The Problem

In the next decade the conflict between economic growth and pollution abatement can reach even greater intensity than at present. The brown-out, the shortage of natural resources, the rising prices for goods and the rising prices of disposal, and the social conflict engendered by the attempt to allocate public priorities will all be part of the process of trying to adjust the behavior of an industrial society which has reached the diseconomies of intensive use of nature. Adjustments are nothing new to rapidly changing societies and there is good reason to believe that an accommodation will be reached before the predictions of the doomsday survivalists can come true. However, the adjustments are several. In this report we seek to open up the vision of alternatives available to government and private industry as they cope with the conflict between economic growth and pollution abatement.

It is the central thesis of this report that the conflict need not be inevitable and the practices which will minimize the conflict are within the realm of reason, even within the value systems we have in the nation today. Most of the report is technical and specific in terms of how to accomplish the goal, but some attention must be paid to the larger issues, for the feasibility of applying solutions lies in the will to accomplish change.

If we leave the conflict of goals unfettered, no advocate will be able to silence another, for economic growth has deep roots in American expectations and the new concern over pollution abatement will be with us as the environment saturates and even marginal increments create unexpected damage. There seems nonetheless, to be little practical thinking on all sides that face the fundamental issues. The visionaries are impractical and the practical men do not see that the consequences of continuing present "practical" behavior are highly impractical indeed. Some attention to the relation between the short and long run is needed, for when dealing with nature's rejection of industrial behavior, the long term creeps on us quickly.

Under the present abatement strategy of putting restrictions on point sources of pollution, the retardation of economic growth is inevitable, for the reductions in emissions gained are wiped out by the growth in number of emitting sources. Los Angeles reduced the number of emissions per automobile with the legislation applying to each car and for some time the downward curve of pollution was encouraging. However, today the curve is upward again as a result of the increasing number of automobiles. The same story will repeat itself in other instances as well. Industrial restrictions requiring even high efficiency of abatement will be overcome by the increase in the number of producers and their per unit size. Unless we move to a policy of zero emissions in the high growth industries--and the marginal costs make that a very costly price to pay for cleaning up--we are going to restrict economic growth to maintain good standards of environmental quality.

Present policy seeks to achieve ambient air quality or water quality or the quality of other environments by regulating emissions at the particular source. This approach creates new problems for it sometimes transfers problems from one part of the environment to another rather than really solving the problem. Cleaning smoke stacks with aqueous solutions can create water problems. Burning off solid wastes can create air problems. An integrated approach is necessary to avoid this form of transfer rather than solution. The creation of the integrated Environmental Protection Agency will help alleviate the situation, but integration will not succeed unless there is a management tool available to make the trade offs necessary. Furthermore, if data is collected in present categories, no amount of liason activity will be pervasive because data is now collected with a predisposition to disposal rather than alternative uses of the wastes. Disposal leads to treatment or isolation of the effluents, missing opportunities for re-use.

Perhaps the most important limit of treating emission standards on the basis of points of source of pollution is that thinking about single sources does not give attention to the possibility of putting sources together for meeting quality standards by re-use or shared disposal costs or other activities which we will discuss. In sum, looking at trees makes it difficult to see the forest and the long term solution will require the broader look. Economic growth requires an integrated and broad view. If the public is not going to have to pay too much for its health and welfare, considerations for maintaining quality through a variety of strategies will have to be considered. Regulations on single sources will always be necessary, but supplementary analysis will have to go on to achieve effective and optimum abatement strategies in the economy as a whole. How the single sources are abated is a matter for environmental management and the single source regulations must be supplemented and put into a larger context.

One supplement to regulations at the source of pollution is a comprehensive recycling policy which encourages complete utilization of by-products. This approach also hits limits very early because it assumes that more materials are recyclable than in fact are--within the constraints of a marketplace responsive to consumer tastes and free enterprise production. A major change in values will have to occur before comprehensive recycling becomes a reality.

Another supplement is to ban the production of products which lead to problems of waste disposal and pollution. While this approach has merit for some limited areas of the economy, it creates an intrusive interjection of government in affairs where the state of the art of forecasting damage from new chemistries of production is only fair at best.

The most pessimistic solution is zero growth policy and that simply is not acceptable to large groups in the society who have yet to taste the delicious despair of affluence felt by the literati writing from their summer homes in the country. Such an approach out of the mainstream of American life is an imposition on people who have not yet achieved America's promise.

All of these approaches have something to commend them for some portion of the problem. Indeed, in pursuit of the health and welfare of the people, all of these approaches must be utilized for some portion of the problem. However, the approaches get in the way of each other. Government emphasis on subsidizing treatment plants hinders possible recycling potential. Point source regulations force investments in abatement technology when money could have gone into other areas with better long and short term payoff. We need a way of setting disaggregated policy which applies differentially according to the dynamics of public demand, variety of industrial practice and the decentralization of decision making inherent in our economy. Structurally that is a tall order for a problem as complex as pollution abatement.

It is even more difficult when we include in the problem that government has a responsibility to the environment which includes some rationing or intelligent allocation of scarce non-renewable resources. There are always cassandras who will say that in such and such a year we will run out of this or that precious commodity. These projections have often been confounded by the discovery of new sources in nature, new technologies which substitute materials, or a reduction of projected demand. However, at the current rate of population expansion and the utilization of natural resources, the dire predictions seem saner than ever before.

Thus, when we see the conflict between growth and pollution abatement and the need for thought about natural resource allocation, the problem takes on large dimensions which require some new and complex approaches to the solutions.

Whatever approach is ultimately taken, we would like to see two major purposes served. Our first purpose is to minimize the conflict between economic growth and pollution abatement techniques by examining opportunities which are often overlooked. We would like to convert wastes into resources and therefore relieve the pressure which using virgin materials makes both on the productivity of our natural environment and on the environment's capacity to absorb wastes. Our second purpose is to create an information system which clearly identifies the empirical possibilities available within the pollution abatement strategies considered. We would like to find actual cases of the applications of different strategies so that we can optimize among alternatives with data which makes intelligent management possible. Our interest is to evaluate, by counting the actual number of possible cases, one strategy over another. We would like to replace rhetoric with facts. We want to show limits as well as opportunities and make environmental management a science as well as a moral imperative.

Before the advent of massive data processing, the cybernetic approach to the problem would have been impossible. Information control of national industrial production by monitoring material flows to direct resources is still out of step with reality. However, we are in an era in which information can be gathered to meet the requirements of a policy needing the coordination and flexibility suggested above. In this report we suggest a way of determining the minimum data needed by integrating data sets with abatement strategy; a way to maximize useful information by collecting data in the context of its use--and a systematic way to judge alternative approaches for particular industries in a decentralized economy. We take on a large obligation in setting out in this direction, but the obligation must be commensurate with the problem or this proposal too will fail. We call the approach an Ecosystem of Machines Information System (EMIS).

The idea of an ecosystem of machines comes from pressing a biological analogy such that the output of some machines can become the input of others. We conceive of machines as organs in an interacting organism called an industrial economy. Without having to press the analogy any further, we can build on the basic ideas so that inputs from virgin materials might well be replaced by outputs of other machines now classified as wastes. These wastes can be converted to resources by their collection and processing to replace virgin materials. The closed loop or cycle of materials would be the ultimate application of biological reasoning to industrial production. However, as suggested earlier, recycling of materials has important limits and we must accommodate reality still further.

In addition to recycling materials the information system must be able to indicate where substitutions of processes can avoid pollution damaging to the natural ecosystem or the wasteful use of non-renewable resources in short supply.

Failing both of these alternatives, some form of disposal must be achieved and hopefully, the disposal can be done in a way which returns the material to some natural use in the natural ecosystem or stores it to enter the mechanical ecosystem at some other date.

The idea of an ecosystem of machines allows us to pursue each of these alternatives in some detailed way suited to a broad range of industries and processes. Among the major limits to applying the ecosystem idea is the lack of information in the marketplace to encourage this closed loop behavior. There are other limits, more fully discussed in Chapter 5, but the availability of information is the most critical at the outset.

Improving Information

There was a time when we believed that the marketplace would act to incorporate pollution reduction costs in the same way it had worked to lower the costs of industrial production. Until experience showed that industrial plants designed in New York City were shipped to regional locations where the design simply did not take into account the presence of local markets for effluents or local sources of raw materials; until other experience showed that excessive treatment costs were borne by a large group of metal finishers who could have banded together and actually been paid for their wastes; until experience showed that separate municipal and industrial waste treatment plants were planned within one year of each other without communications that would have allowed for mutual savings; until experiences like these multiplied, we did not realize the need for systematic information.

Contrasting examples of success were also important for our reasoning. Large chemical companies, which know a great deal about themselves, realize the value of recapturing and have active programs. Fly ash producers have now banded together to make fly ash a part of the building industry materials. New industrial parks are being built with shared treatment facilities. Some paper mills now have their sites determined by ecologists. All these signs of success point the way but they are too sporadic and localized without an institutionalization of the process to make them occur throughout the economy.

It was while recording the failures and successes over the last years we came to design the systematic way of locating opportunities for pollution reduction here proposed. The computer allows us to make two major additions to what the marketplace already signals. First we took the central ideas involved in pollution control and generalized them into software design. We have reduced these ideas so we can write computer programs which take the basic logics of analysis and convert them into principles of interrogation for finding possible pollution controls. Secondly we have investigated ways to build a large data base which will provide information helping to locate industrial residues lost in the normal process of production and marketing.

The first effort of building the software aims to make the ideas of experienced consultants available to many people, making the consultants more valuable by expanding their applicability. The second effort on data gathering brings information together for which we have traditionally had to rely on experienced men with a wide range of exposure to different industrial processes. We can now record the relevant information and let the "experience" be brought together where many conferences and cocktail parties would have failed. (Let us hasten to add that we have no intention of replacing either conferences or cocktail parties. Men live not by computers alone. However, we are going to augment men's efforts and make them more effective, while reducing travel budgets.)

The systematic identification of pollution reduction measures without reducing economic growth leans on the pervasive biological analogy of an ecosystem of machines. We conceive of an industrial network as if it were an ecosystem composed of machines with input and output materials related to each other. Less ambitious than an input-output matrix of materials flow, but more ambitious than simple by-product marketing, we construct a computer matching service to identify networks of materials and producers.

In Chapter Two we outline the design for the systematic identification of potential matches of industries, listing the basic computer routines. In Chapter Three a sample data base is indicated and processed through the alternative strategies for abatement. In Chapter Four we investigate the present practices of abatement policy and suggest the increased opportunities through the EMIS method. In Chapter Five we outline one dozen reasons our approach will not work and one dozen requirements which are raised by these objections. In the conclusion we summarize the position taken and suggest what steps are necessary to get on with the job of harmonizing the need for economic growth, pollution abatement, and rational allocation of limited natural resources.

Chapter 2 Design for a Systematic Identification of Alternative Strategies for Pollution Abatement

EMIS Routines

EMIS operates by formally setting the dominant strategies toward pollution abatement into computer software as a set of systematic questions which can be asked of an expansive data base. The fundamental strategies are recovery, recycling, and reuse in different industrial processes; substitution of offending operations by less polluting processes; and waste treatment and disposal. When translated to formal reasoning, the essence of recycling is an algorithm which matches producers and consumers of the same material such that those industries which release harmful effluents or scarce resources as wastes can be matched with those industries which use the equivalent of those wastes in virgin materials. The matching process then identifies potential partners for converting "waste" into a resource by recycling within a single plant, or by recovery and recycling within the total or regional economy. The matching algorithm makes positive identification of partners.

In a generalized and simplified equation, the algorithm for the recycling computer matching is $A_i = A_j$ where i and j are two different industries and A is a material used in production as an output or input.

The strategy of substituting less polluting processes for existing ones can seek empirical content in the data base by looking for the algorithm to be satisfied as $g = f$ or h or n where g is a function or process and f, h and n are functional equivalents.

The strategy of waste treatment and disposal seeks partners who can share the cost of treatment or treat each other's waste. The algorithm which finds these opportunities in the data base can be written in a simplified form as $b_i = b_j$ or c_s where b and c are dumped wastes and i and j and s are different industries which can share facilities.

These basic strategies are amplified in the processing by many more variations. There are also feasibility tests. However, the essence of EMIS is this matching process to identify potential partners to increase recovery, substitution, or shared costs of treatment. Each of the EMIS routines is based on each of these formal statements or some variation thereof. The routines are used in a matrix of industries in the national industrial network which we conceive of as an interacting set. The routines are defined below.

Since there are a great number of processes and industries, our first step is to list the processes and industries by the Standard Industrial Classification (SIC) and to construct a matrix for interaction which will be systematically scanned for industries which can relate to each other. The rules for establishing potential relations are found in selected logical routines which interrogate the data base in the following fashion.

SYMBIO is the routine which searches for industrial processes which use, as inputs, polluting emissions from another industry's output. In essence, the search is a systematic and comprehensive by-product identification routine. It matches potential partners for symbiotic (mutually supportive) relations.

CONCOV is the routine which searches the list of pollution abatement devices which potentially may convert a pollutant into a valuable input for another industry. It operates on the premise that there is a choice of control devices and some control techniques may convert pollutants to resources which can then be identified by SYMBIO.

SUBPRO is the routine which identifies processes which perform similar functions but are less polluting in order to see where substitutions can be made.

SHAREC is the routine which identifies processes which use the same or similar abatement procedures to explore the possibility of shared pollution control facilities.

The four routines above are based on comprehensive and systematic matching of selected industries in the Standard Industrial Classification. The matching process is augmented by three other routines which serve different purposes.

HARCOR is the routine which accepts the residual products which cannot be used by any industry and seeks the alternatives for their ultimate assimilation and natural recycling or isolation from the environment. These hard core residuals are the rejects of the scanning system.

TECFOR is the routine which updates the elements of the system for projected rather than present technology and gives information concerning increasing or decreasing rates of change of the magnitude of processes in use.

FEASPO is the last logical routine. It determines the economic feasibility of taking one of the alternatives which match potential partners. This routine can also be manipulated to give the optimum strategy based on comparing the results of the various routines.

SYMBIO and CONCOV are essentially by-product routines. In these routines the system takes outputs of industries, which are now classified as wastes, and matches them with industries which can use the materials as inputs to their processes. This matching gives us the alternatives open for recovery, recycling, and reprocessing of materials. In these routines all possible matches are searched and the availability of control devices to convert materials into usable material is also investigated. These routines will identify the use of a by-product within one industrial process, within two processes of one industry, or between two or more processes of two industries. In these routines EMIS will try to achieve the maximum amount of re-use of materials.

SUBPRO is the next step after failing to achieve a re-use of emissions. If it's impossible to re-use by-products of a particular industrial process so that pollution can be held to a tolerable level, EMIS will use SUBPRO to search for a process which may be substituted in order to reduce this pollution or increase the re-use of by-products. This alternative strategy has been used to reduce air pollution from power plants by changing fuels. SUBPRO would consider materials in general categories, thus identifying unthought of and unusual substitutions.

If by by-product re-use and substitution, EMIS fails to achieve the level of pollution reduction desired, it will investigate the use of common facilities to dispose of wastes (SHAREC) and attempt to insure that those wastes do not harm the rest of the functioning ecosystem or find a way back to a natural state (HARCOR).

SHAREC functions as a collector of industries which may share either a control device or a dumping strategy. It seeks to group industries and/or processes which otherwise would not be able to utilize these pollution reduction measures. All HARCOR strategies apply to these collections made by SHAREC.

The last logical routine is FEASPO. It determines the feasibility of decisions about matching potentials and about future technical changes. Feasibility is a function of economic and social policy regarding pollution reduction for it sets the parameters in which industry will operate. The previous policy of letting the first user have priority on the environmental resource is now changing as each new user has more damaging effects. The abatement restrictions by governments, the corporate policy as a response to public pressure, the fluctuating known supply of raw materials and the value placed on them are all matters of policy which affect feasibility.

In each case of the above routines, constraints were mentioned regarding costs of transport, location, availability of materials in a region, stability of supply, and such other considerations. In FEASPO we store the economic and social policies in terms of their economic implications for cost accounting. In this way we can be sensitive to market adjustments and make policy both as an initiator of behavior and also in response to marketplace behavior.

If rigidly done in computer analysis, the rapid updating requirement could take an enormous amount of time and suffer from overcentralization. Therefore FEASPO will require a man-machine design which allows the experience of a small staff of knowledgeable men to be current with activities and local variation. Their information can then affect the calculations in the other routines and allow the information system to operate with and ahead of the times rather than behind them.

FEASPO also can be manipulated to give the optimum strategy based on comparing the results of various routines. It can be used as an optimizing routine which recommends the costs of various alternative activities. It will compare the results of SYMBIO and CONCOV, the two by-product routines; with SUBPRO, the substitution alternative; with SHAREC and HARCOR, the waste disposal alternatives. For example, under a national economic and social policy encouraging recycling, the feasibility of choosing one of the by-product alternatives would be taken over a waste and dumping strategy.

The seven routines provide the necessary information for interrogating the data base to match related industries which could use the pollutant of one as the resource of another. They can also be used to optimize abatement strategies among the alternatives generated by the system. A staff operating EMIS, either in a batch processing mode, or for more detailed and complicated interactions, in an on-line interactive mode, can search for partners to lower the costs of pollution abatement. EMIS compares alternative strategies which would go undiscovered by traditional techniques using a lesser amount of information and habitual communications within and among industries.

Information System Structure

The main features of the Ecosystem of Machines Information System will be

Data Storage--variable number of fields per record. Unlimited number of records per file. Sequential storage of records.

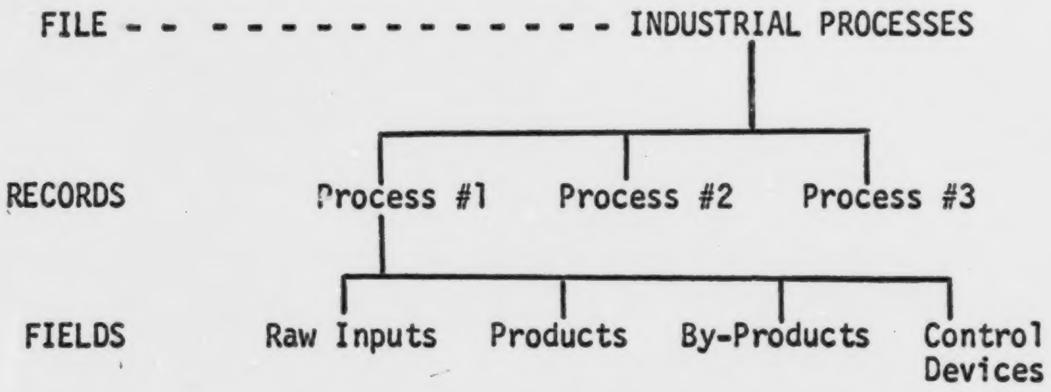
Data Input--editing of input data through clerical and value checks on input data.

Data Output--pre-programmed report formats using logical selection criteria for output data. (Subject to further discussion.)

DATA STORAGE--The relevant industry data and the industrial process information on which EMIS operates constitute the information system data base. The data in the files will be organized to facilitate their use by the computational routines: SYMBIO, CONCOV, SUBPRO, SHAREC, HARCOR, TECFOR AND FEASPO.

In the Ecosystem of Machines Information System the files would be generated and maintained by a generalized file maintenance routine and would be stored on a random access storage device such as a disk memory device. This would allow for optimum access time in relation to storage capacity, in supporting both file maintenance and data output.

The data for this system will be hierarchically stored in fields; several fields representing a record; and several records constituting a file. At the top of a hierarchy the file designates the general nature of the data to be stored (e.g. an industrial processes file or an industry type file). Records are the next level in cataloging the contents of a file. For an industrial processes file, for example, a logical record breakdown would be by industrial process types such as Kraft, Sulfite and NSSC for the pulping process. The lowest level in this system is the field, a unique piece of data associated with the record.


FILE
INDUSTRIAL PROCESSES
RECORDS
Process #1
Process #2
Process #3
FIELDS
Raw Inputs
Products
By-Products
Control Devices

DATA STORAGE ORGANIZATION
Figure 2-1

Thus, working up the hierarchy in Figure 2-1, by-product (emission) of a specific industrial process would be contained in a field within an industrial process record within the industrial processes file.

DATA INPUT--A pre-edit routine and a generalized file maintenance routine will be used in processing input data. The pre-edit routine will accept new data inputs and convert them to a form that will permit efficient updating in the generalized file maintenance routine. In making this conversion, the routine will make clerical and value checks on the input data to insure that the data is usable.

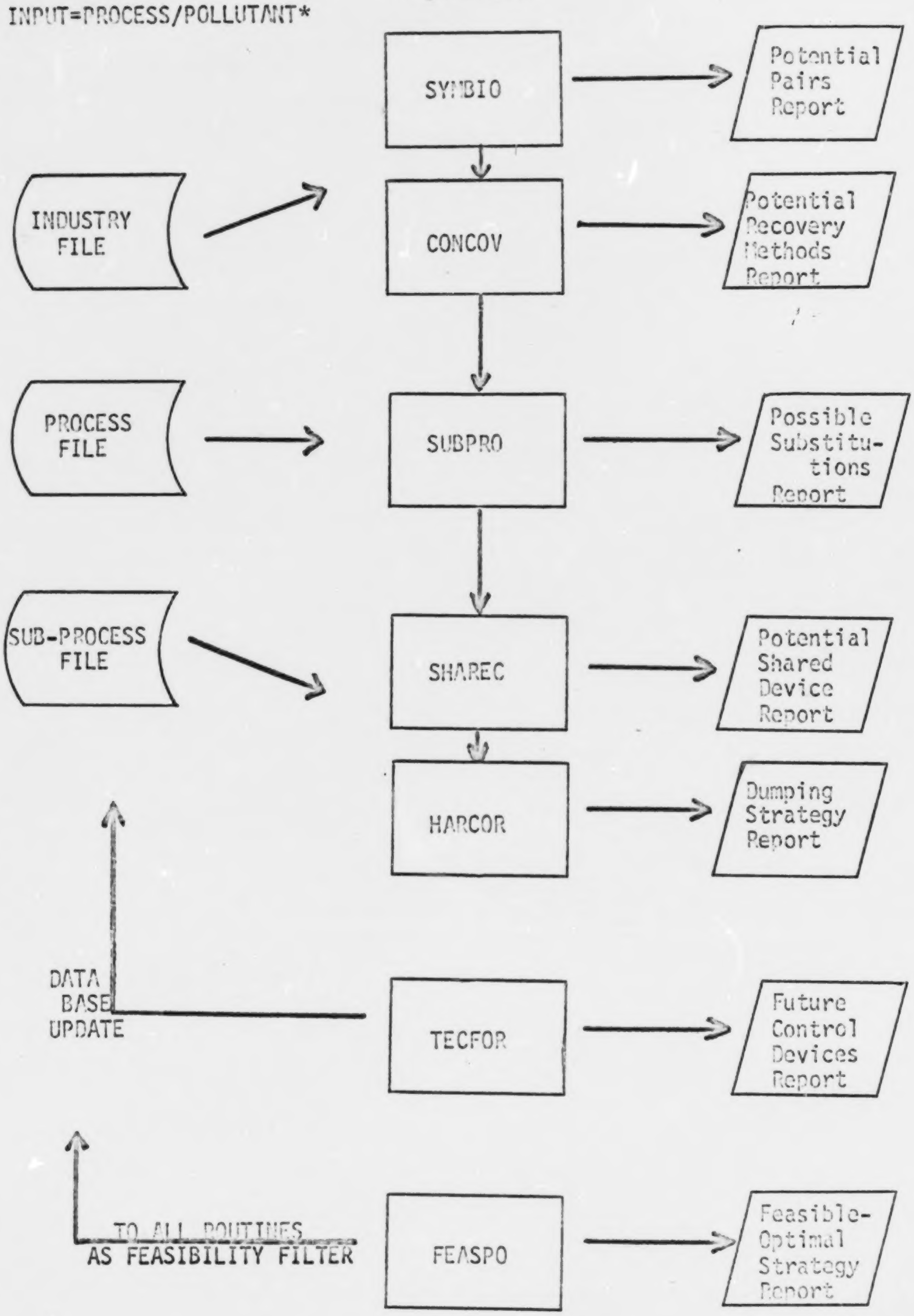
DATA OUTPUT--The Information System would provide two types of output information: (1) a printed listing of information stored in various files and (2) a summary output based on pre-programmed report formats (see description of computational routines for a more detailed description of the output). A computerized Information System would be written utilizing a general purpose computer language. This will allow the system to be changed easily to reflect future requirements; and to be usable on any computer system (with slight modifications necessary on some) which has the general purpose language compiler available.

In this preliminary look at the information system, it is too early to describe the exact operational details of such a system. However, the system would provide the storage and retrieval functions necessary to supply data to the seven computational routines. The proposed system flow for EMIS is delineated in Figure 2-2.

A full pass through the system begins with SYMBIO which searches for industrial processes which use as inputs emissions from another industry. Any matches here are fed through the feasibility filter (FEASPO) to determine whether they are truly opportunities. If opportunities do indeed exist, a Potential Pairs Report is generated and the system moves on to the next sequential routine, CONCOV. If no symbiotic opportunities existed in this particular case, no report would be generated and the system would move immediately to CONCOV.

EMIS will move through CONCOV and SUBPRO looking for potential recovery methods and/or alternative processes. If matches are found, reports will be generated. In each of these cases the feasibility filter (FEASPO) will be utilized to insure possible matches.

INFORMATION SYSTEM FLOW DIAGRAM
Figure 2-2


INPUT=PROCESS/POLLUTANT*
SYMBIO
Potential Pairs Report
INDUSTRY FILE
CONCOV
Potential Recovery Methods Report
PROCESS FILE
SUBPRO
Possible Substitutions Report
SUB-PROCESS FILE
SHAREC
Potential Shared Device Report
HARCOR
Dumping Strategy Report
DATA BASE UPDATE
TECFOR
Future Control Devices Report
TO ALL ROUTINES AS FEASIBILITY FILTER
FEASPO
Feasible-Optimal Strategy Report

*Access to the system can be provided at any or all routines. Feedback loops have been omitted for simplification of presentation.

The next sequential routine, SHAREC, will attempt to identify processes which use or could use the same or similar abatement procedures. Any matches which successfully pass through the feasibility filter (FEASPO) will be printed on a Potential Shared Device Report.

When the system reaches HARCOR, the routine will accept residual products which cannot be used by any industry and seek the alternatives of their ultimate assimilation or isolation from the environment. These hard core residuals are the rejects of the systematic scanning for potential partners by the other routines.

In this manner the information system attempts to identify all possible potential partners. Not only are rejects from each routine passed to the next sequential routine but already identified potential partners are passed also. This allows the feasibility filter to compare potential partners immediately. After the rejects of the scanning system are processed by HARCOR, the list of potential partners for pollution reduction will be passed through FEASPO again. During this final pass, FEASPO will generate an optimal strategy report which will compare the various abatement alternatives and make recommendations concerning the best choices.

Due to the large size and rapid obsolescence of the EMIS data base, the information system is designed to be a man-machine system. It would be impractical to attempt to keep the data base current on a daily basis in functions such as the following: raw material availability and price; current events affecting certain geographical areas or industries. It is essential that EMIS be current and sensitive to variations.

This will require the utilization of knowledgeable men whose experience can broaden the scope and impact of EMIS. They will have on-line access to the system to explore variations on basic output.

The man-machine design of EMIS improves the utility of the system. The information system through its systematic scanning of the data matrix will produce potential partners for pollution reduction. At this juncture the man can, with the use of additional data, more current data or judgement, expand or reduce this list of potential partners. He will also be responsible for updating the data base of the information system and reviewing the logic by which it matches potential partners. In this manner the information system will learn from its mistakes and grow to be a better tool for its users over a period of time.

The data required to perform these operations are substantial in quantity and quality. Whenever new major accounting systems are created, the data problem is a great part of the implementation effort. Indeed, when national income accounts were created to calculate GNP and to facilitate manipulation of the economy, a major commitment was made to data conceptualization and collection. In a pollution accounting scheme which has the potential breadth of EMIS, the data problem will be very serious indeed. In some sense, data collecting will never be finished for as the system expands, data requirements will grow. However, as long as the system is providing environmental managers with useful information, the data effort is justified. Even without EMIS, the magnitude of pollution data which will be collected in the next few years will be substantial. EMIS's contribution is to help identify the data design and organization so that the effort will pay off for environmental management. If EMIS starts in the right direction as a management tool, then the substantial data which it requires will be put to a use so that it will more than pay for its costs.

The data problem must then be put in perspective and that is a long term view. The more we demand of the system the more it will require in its data base, but modest demands on early versions of EMIS can be met relatively soon and we have investigated the possibility of establishing a data base for modest levels of utility in a limited framework which can be derived almost from existing data. With this capacity to hold the level of utilization consonant with existing or near-existing data, we can offer some feasible output even before a major data collecting effort is launched.

This judgement is based on several sources of existing data and what we have been calling near-existing data. The existing data which has come from federal and state government pollution agencies is substantial in amount, and although not always applicable to the range of strategies in EMIS, we have a substantial start. Among the agencies which have collected pertinent data for some part of EMIS are NAPCA, FWPCA, BSWM, USGS, B of M, and the Census for pollution data and the OBE model for economic data. As we investigate still further in these agencies, we find more and more potentially useful material and a willingness to alter categories to be applicable to the kinds of decisions which EMIS will facilitate. The Division of Process Control Engineering in NAPCA has independently begun a selective data base which, if continued, would feed exactly into the management decisions which EMIS can facilitate.

We have also alluded to a near-existing data base. By this we mean two levels of development. Firstly, we expect that existing sources will have quantitative and qualitative improvements in the next few years. The creation of EPA should stimulate the kind of integrated data necessary and if we can establish useful integrated data collecting categories, the effort of this Agency can greatly improve what will soon be existing data bases. The Department of the Interior is also seeking new data for water quality management and they will expand what is available very shortly. Thus, as more and more areas of pollution control come under government scrutiny, the data requirements are gradually fulfilled. The essential element in this optimism is that thought will be given to the qualitative dimensions of data collecting so that a broader range of management decisions will be possible than mere treatment and disposal.

The second category of near-existing data refers to data which we can infer from known processes. The Stanford Research Institute collects an enormous amount of data about industrial production which, while it is not all directly applicable, is the basis for inference of a part of our data needs. In the Chemical Economics Handbook and in the Directory of Chemical Producers there are substantial lists of products, plants, areas, capacities, and processes which can be expanded to our needs. If we concentrate on Standard Industrial Classification for Division D, manufacturing, the basis for extrapolation to pollutant data is not far off.

One limit is that small producers are not included, and in some fields that is an important loss, though nationally it is perhaps tolerable. The second limit is that some of the detailed by-product information is missing and would have to be included to increase the number of matching opportunities. This latter problem is partially resolvable through inference by an experienced engineer, for the missing data has a great number of typical characteristics which can be used to fill otherwise empty data cells. Furthermore, trade organizations have now begun to collect data relevant for recycling as industries seek the alternatives for lowering costs. This data is becoming available and would greatly supplement the existing capacity. In addition, an industrial subscription service, perhaps organized through the National Industrial Pollution Control Council, could make data available on an exchange basis. Willingness to cooperate in cost reducing control programs will increase as enforcement and legislation proceed.

Within some confidence limits for suggesting possible matches which then would be checked out by the interested industries, this near-existing data base can be very useful. Once again, if we expect that our demands can be held down in the first year or two of development, this near-existing source can be applicable to a range of useful decisions.

In addition to the pollution data which exists or near-exists in a technical sense, there is also another set of sources of near-existing economic data. Project EQUIPS, a joint agency study housed in the Department of Commerce, has set out to derive data from the Office of Business Economics input-output matrix and while this effort is only in a pilot stage, it could produce some near-existing material, especially if the input-output approach is pursued with vigor. Professor Wassily Leontief of the Harvard Economic Research Project has expanded the input-output model to include pollution management considerations and that framework for data collecting is highly compatible with parts of EMIS. (See, Wassily Leontief, "Environmental Repercussions and the Economic Structure: An Input Output Approach", The Review of Economics and Statistics, Vol. LII, No. 3, August 1970.) These efforts, and others which are just now beginning, bode well for future data sets.

In spite of these good signs, there is still no reason to minimize the cost and time which a full scale operating national data base will ultimately demand. If the system is to achieve widespread applicability and depth of detail in analysis, then the data will have to be correspondingly rich. However, the system can be built incrementally and its utility can expand and be demonstrated before next steps are undertaken. In this fashion, investment in data can be kept proportional to return.

The massive amount of data will be a disadvantage unless it is possible to organize it efficiently. EMIS has a systematic data handling system for this purpose. Three separate data files containing industry characteristics and industrial processes characteristics are the basis of data handling. These files, referred to as the Industry File, the Process File and the Sub-Process File, will communicate directly with the computational routines providing the data for output reports selected by the user. The relationship of these three files to one another is shown graphically in Figure 2-3. Examples of the types of data to be contained in these files are shown in the final section of this chapter.

INDUSTRY FILE

Field Name	Description
1. Industry identification	By SIC code
2. Industry descriptive name	A word description of the industry
3. Ownership	Private, local government, etc.
4. Location	Relative location of plant
5. Major processes used	List of processes by code number
6. Manufacturing process units	Tons/day, pounds/hour, etc.
7. Control devices used	List of control devices by code number

PROCESS FILE

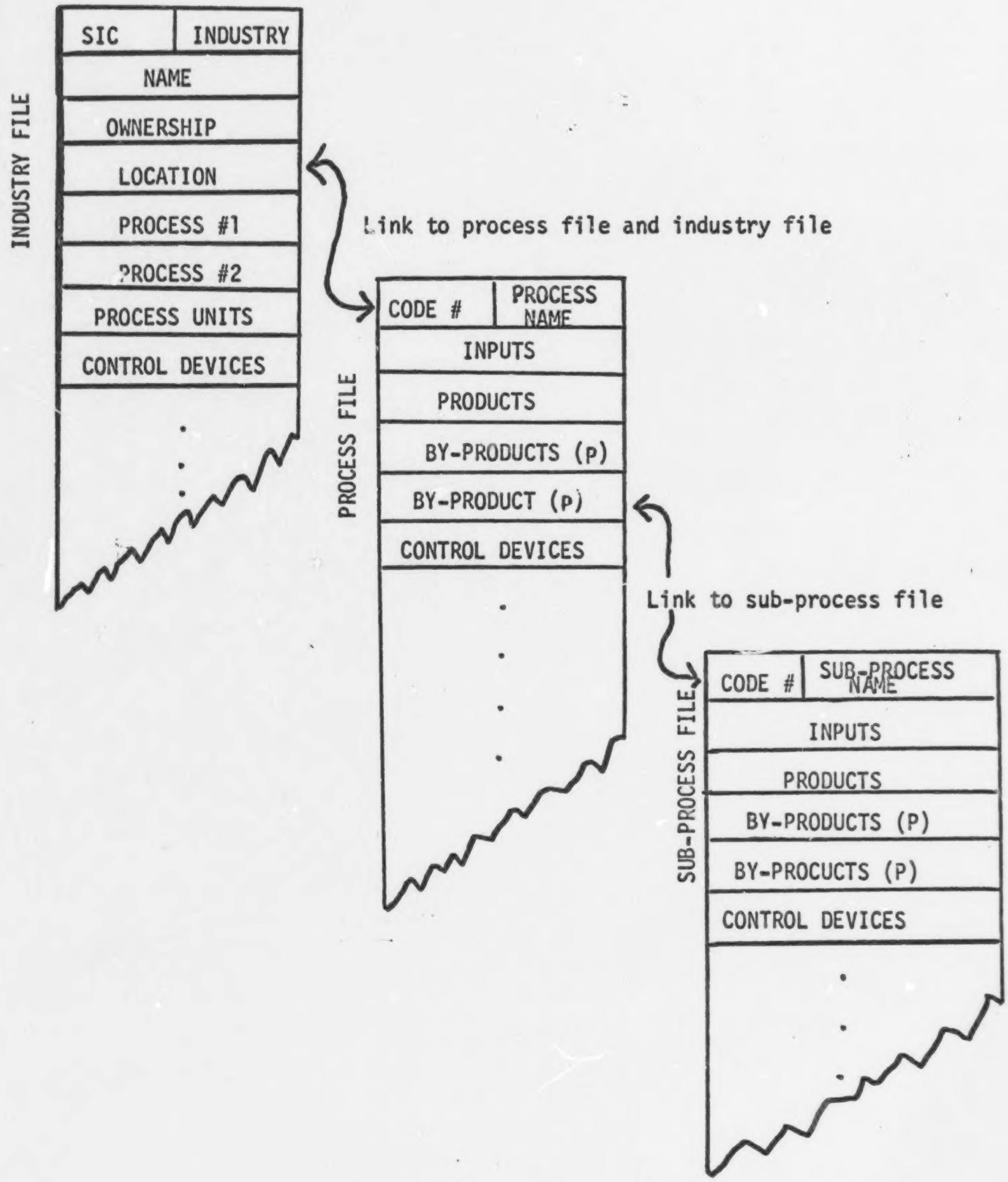
1. Process identification	By code number (SIC plus suffix)
2. Process descriptive name	A word description of the process
3. Raw inputs	List of inputs by code number
4. Products	List of products by code number
5. By-products	List by code number (plus suffix) e.g. D=dump P=pass
6. Control devices available	List of control devices available by code number

SUB-PROCESS FILE

1. Sub-process identification	By code number
2. Sub-process descriptive name	A word description of the sub-process
3. Inputs	List of inputs by code number
4. Products	List of products by code number
5. By-Products	List by code number (plus suffix) e.g. D=dump P=pass
6. Control devices available	List of control devices available by code number

FILE LINKS

Figure 2-3


INDUSTRY FILE
SIC
INDUSTRY
NAME
OWNERSHIP
LOCATION
PROCESS #1
PROCESS #2
PROCESS UNITS
CONTROL DEVICES
Link to process file and industry file
PROCESS FILE
CODE #
PROCESS NAME
INPUTS
PRODUCTS
BY-PRODUCTS (P)
BY-PRODUCT (P)
CONTROL DEVICES
Link to sub-process file
SUB-PROCESS FILE
CODE #
SUB-PROCESS NAME
INPUTS
PRODUCTS
BY-PRODUCTS (P)
BY-PROCUCTS (P)
CONTROL DEVICES

EMIS Operations and Use

There are different scenarios for the use of EMIS. One possible situation would have EMIS installed in a government agency with a small support staff. Monthly batch runs might be used to generate a great number of matches for later close analysis. Or, particular pollutants or particular areas might be scanned for alternatives. When the first pass of possibilities was uncovered either at the macro level or within some constraints of materials or geography, the staff could pursue the possibilities in some detail by contacting the industries involved to get more data or to alert them to the possibilities which appear to be worthy of exploration. Enforcement agencies could also request alternatives to offer the industries they were encouraging to comply. At present the design is for highly open access in order to allow a broad or narrow form of interrogation of the data base. With this kind of unrestricted access, a number of tasks could be performed.

Let us assume that the first user is a program planner entrusted in government with the task of encouraging re-use of materials rather than collecting and dumping. He is interested in finding opportunities which the marketplace has not signalled. EMIS gives him the basic data to know whether there are real alternatives available and whether or not his mandate is a realistic one. The data in EMIS will include what he needs to know about the type of industries and processes used in his area of concern. He would under one scenario, proceed through the system as follows:

He would begin by scanning the Industry File. The Industry File itself would include the SIC code and relevant descriptive information such as location of present plants, ownership, major processes, sub-processes, products and by-products, and type of power plant with fuel used. The Process and Sub-Process Files would also be tabulated by SIC code and would include both unit operations and unit processes. Thus both the mechanical processes such as grinding and crushing which are potential sources of air pollution, as well as chemical conversions would be considered. The process would be described and its inputs and outputs listed. These files would not show a complete materials flow for the process, but instead would concentrate on those chemicals produced in sufficient quantity so as to be potential sources of air and water pollution. They would be described both chemically by analysis and physically as solids, liquids or gases; and their units such as tons per day, or percent of compound in off-gas given.

The Process File would be scanned after the Industry File and would only include the basic raw materials as inputs and the final products and by-products as outputs. For example, the Kraft pulping process would start with wood chips and the particular chemicals of the cooking liquor. Its outputs would include the main product, unbleached wood pulp; and the by-product, black liquor. Then the Sub-Processes would include the various steps that the black liquor could go through in separation of possible by-products, recovery of chemicals and utilization of heat content. This separation of Process and Sub-Process Files is to allow the program planner the choice of main product as output or intermediary products as output.

In his investigations the sub-processes might not follow the main process, but rather be included in the main process. For example, in the smelting of iron ore, the Process File would include the ore, coke, limestone and hot air as the inputs and the wrought iron or steel as the product. The Sub-Process File would include the Blast Furnace with pig iron as its product first and then list the various types of converters or other furnaces which would then be capable of treating the pig iron.

In this file all chemicals would be described both as to their physical state (solid, liquid, or gas) and as to their general chemical properties. Such categories would include acids and bases, both strong and weak and organic and inorganic; oxidizing and reducing agents, again both strong and weak and organic and inorganic. Other descriptive terms such as catalyst and solvent would also be used. In this way, substitutions based on the particular property involved might be made. All by-products would include a letter after their SIC code number indicating whether at present they are used in some manner or dumped.

With these data collected in these various files the program planner has a wealth of information available to design programs. He can scrutinize the programs according to the routines SYMBIO, CONCOV, SUBPRO, SHAREC, HARCOR and TECFOR, as previously described. These routines can thus act as a systematic technique for pollution control: not by collecting, neutralizing, and discarding; but by demonstrating uses.

The array of potential uses can then indicate where incentive and disincentive programs can be designed to encourage re-use. Through tax manipulation, or mere suggestion to industry, or the provision of grants for municipal services such as roads and utilities which would make networks feasible--through all such programs the opportunities can be exploited. FEASPO will evaluate them.

In another scenario we might project a series of industrial users faced with decisions for which EMIS is designed to provide useful information. Companies can make decisions on recycling within a process or within several processes. They can make decisions on future expansion or contraction and they can use their present location as an asset and plan a future location by the new raw materials shown by the computer routines.

For example a company involved in smelting copper ore has the choice of several types of control processes; and the choice of producing sulfur in different compounds. The decision as to which control process to use should be made by the economic picture of possible markets for sulfur compounds in the area. Then too, the decision to use a hydrometallurgical process in place of smelting should be considered in an area where there is recovered acid conveniently available.

EMIS can also be useful for the decision regarding the closing of a possibly obsolete plant. Within the pulping industry for example, there are possibilities of cross recovery processes where spent cooking liquor from one process can be used as new cooking liquor for another process. Co-location of plants using different processes would limit the amount of pulping effluent. Adding plants to process and recover chemicals from spent liquors and also to bleach the pulp would centralize the industry, and then placing this complex near a completely different one which might supply the sulfur and other chemicals for pulping and the acids and other chemicals for bleaching, would greatly enlarge the economies.

In still another instance where there are a number of small companies using the same process or processes, a central waste recovery area could be set up thus allowing high capital costs to be shared. For example, a number of electroplating companies with large acid wastes could benefit from a central facility which allowed them credit on the recovered acid and also could share in the profits of selling the recovered metal salts to neighboring companies.

The network approach could also help an expanding company with its location decision. The possibility of buying raw materials from a recovery facility and sharing a pollution device in one particular region might help costs considerably.

At the present time the trend towards the complexing of chemical plants is progressing in two ways. Firstly, large companies are buying and selling smaller companies in order to fit their economic needs. Secondly, large industrial complexes which share a common system of transportation are forming. The addition of this information would accelerate this trend towards complexing in a manner so as to lessen pollution. It would allow the natural expansion already progressing to continue in a more socially acceptable manner.

In addition to the use of EMIS by program planners and industrial decision makers, the government enforcement official has requirements which EMIS satisfies. If an abatement procedure is too costly and threatens to disrupt employment, the enforcement decision is difficult to take. EMIS proposes alternatives other than restrictions by suggesting cost reducing measures. Furthermore, the timing of enforcement decisions is affected by EMIS. If a central collection facility is possible in a region, uniform timing of enforcement leads to industries joining a central facility whereas piecemeal enforcement does not encourage the economics of re-use.

We have seen this scenario in actual experience. A central facility appeared to be profitable, except that the willingness to join it depended on the time of enforcement and the scattered enforcement pattern spoiled the opportunity. An integrated view of enforcement would have led to a rapid clean-up rather than a failure to re-use materials.

The scenarios can be expanded to include other users ranging from a national land use planner who wanted to create some form of national pollution zoning for industry, to a trade organization seeking clients for materials now classified as wastes. The range of users and scenarios is large, depending on the will to encourage alternatives to collection and dumping.

The remainder of the report is dedicated to demonstrating the feasibility of EMIS to facilitate the decision to seek re-use or substitution, or shared waste strategies as a means to pollution control. By these means, the conflict between economic growth and pollution control is alleviated and the possibility of conserving scarce resources is rendered economically feasible. We can also give empirical substance to evaluate claims for one or another strategy.

Chapter 3 Illustrative Data Base

The pulping and bleaching processes from paper chemistry and the smelting and pickling processes from metal technology were chosen for the sample data base. Both industries rank high in air pollution and also offer wide ranges of gaseous and aqueous inputs and outputs for the Ecosystem of Machines Information System. The ten processes studied in this report include:

1. Pulping--Kraft (K)
2. Pulping--Sulfite (S)
3. Pulping--Neutral Sulfite Semi-Chemical (NSSC)
4. Auxiliary Furnace for Pulping
5. Bleaching--Dithionite
6. Bleaching--Chlorination
7. Steelmaking--Smelting
8. Steel--Acid Pickling
9. Non-Ferrous Metals--Smelting
10. Non-Ferrous Metals--Finishing.

The first three processes represent the most important methods of manufacturing paper pulp. Kraft or Sulfate pulping is an alkaline process which involves hydrolysis of the lignin and uses sodium sulfide and sodium hydroxide in the digestor. At the present time this method of pulping accounts for over 75 percent of the chemical pulp produced in the United States. It is also responsible for the odorous organic sulfides and mercaptans. Since the cooking chemicals are expensive to manufacture, there is often a recovery system built into the process.

The next two pulping processes infrequently have recovery systems built in, but there are opportunities for cross-recovery programs within the three processes. The Sulfite process uses sodium, ammonium, or magnesium sulfite and sulfur dioxide and the NSSC employs similar chemicals and also uses mechanical techniques to accomplish the pulping.

Process number four represents the auxiliary furnace used in the mill. It supplies the energy needs of both pulp and paper production above those furnished by the recovery system. It may be powered by wood-bark, oil, coal, or natural gas.

The two bleaching processes (numbers 5 and 6) oxidize and thus destroy the dyes formed from the tannins in the wood. They include several chemical reactions based mainly on hydrogen peroxide and sodium dithionite and/or calcium hypochlorite and chlorine dioxide.

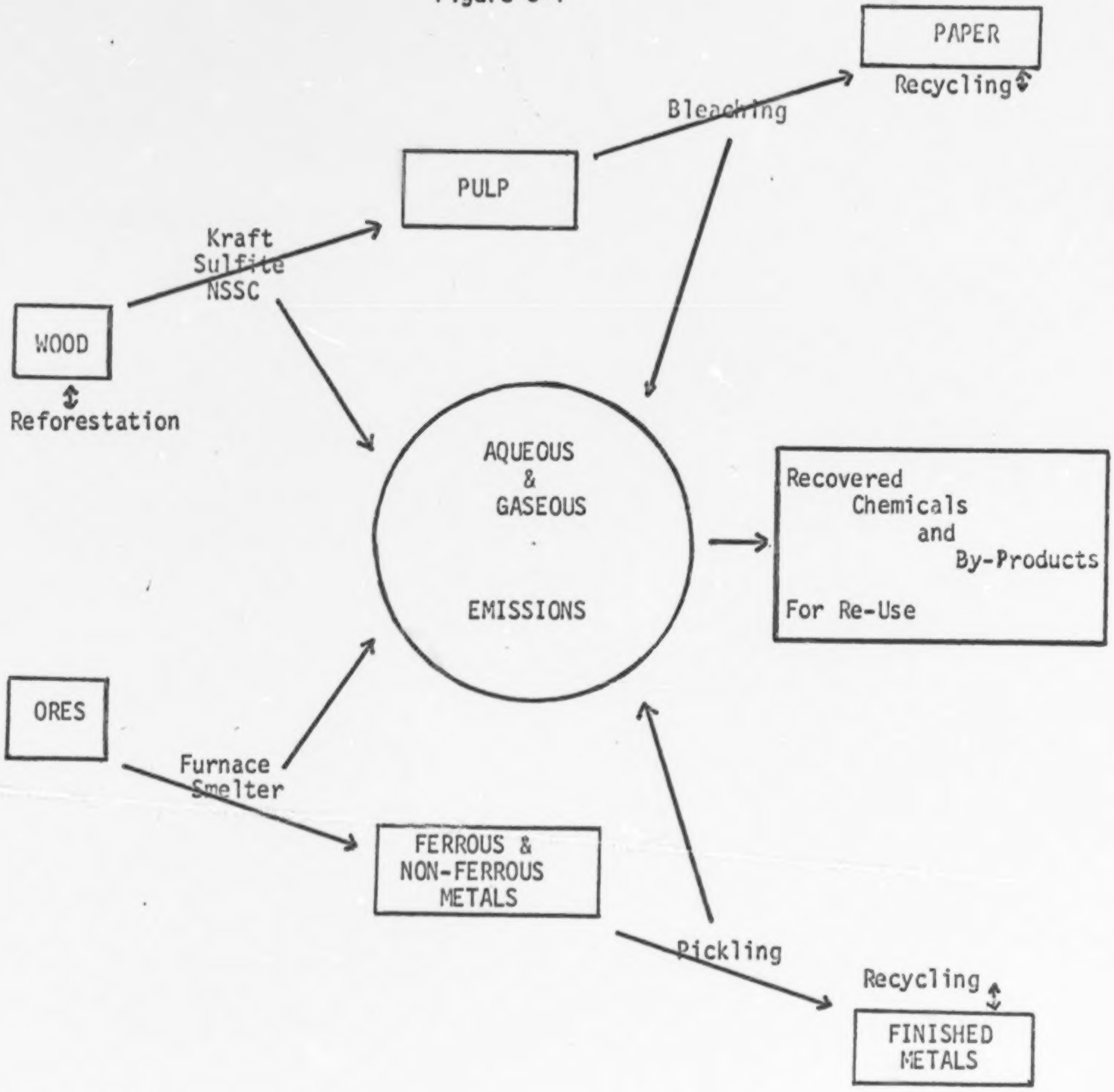
Of the metals processes, number 7 includes the blast furnace and the converting furnaces for steelmaking and process number 9 covers the roasters, reverbs, and converters of copper smelting, and the equivalent furnaces and machines of lead and zinc smelting. Numbers 8 and 10 include all finishing processes necessary to prepare the metal for further use. These include acid pickling and the other chemical cleaning steps.

The general diagram illustrating these processes is shown in (Figure 3-1).

The pollution reducing measures examined in this sample data base were discovered through manual manipulation of diagrammatic

GENERAL FLOW DIAGRAM
OF
the PULPING & METALLURGICAL PROCESSES

Figure 3-1


PAPER
Recycling
Bleaching
PULP
Kraft
Sulfite
NSSC
WOOD
Reforestation
AQUEOUS
&
GASEOUS
EMISSIONS
Recovered Chemicals and By-Products For Re-Use
ORES
Furnace
Smelter
FERROUS & NON-FERROUS METALS
Pickling
Recycling
FINISHED METALS

techniques. These techniques show all the possibilities of combination within the data system according to the computer routines. For example, Figure 3-2 shows all of the possibilities discovered for interconversions within just the processes studied. This figure is the result of using only SYMBIO and CONCOV, within the pulping and metallurgical fields. It does not show the uses of possible by-products from these fields in other industries. Certainly, in a larger data base, these particular data inputs would be used to show all the interconversions within all the industries in that economic region. Also, in this later expanded data base, these manual methods can be replaced by the more efficient computerized EMIS.

The discussion in this section will show these interconversions within the pulping and metallurgical fields by the routines involved.

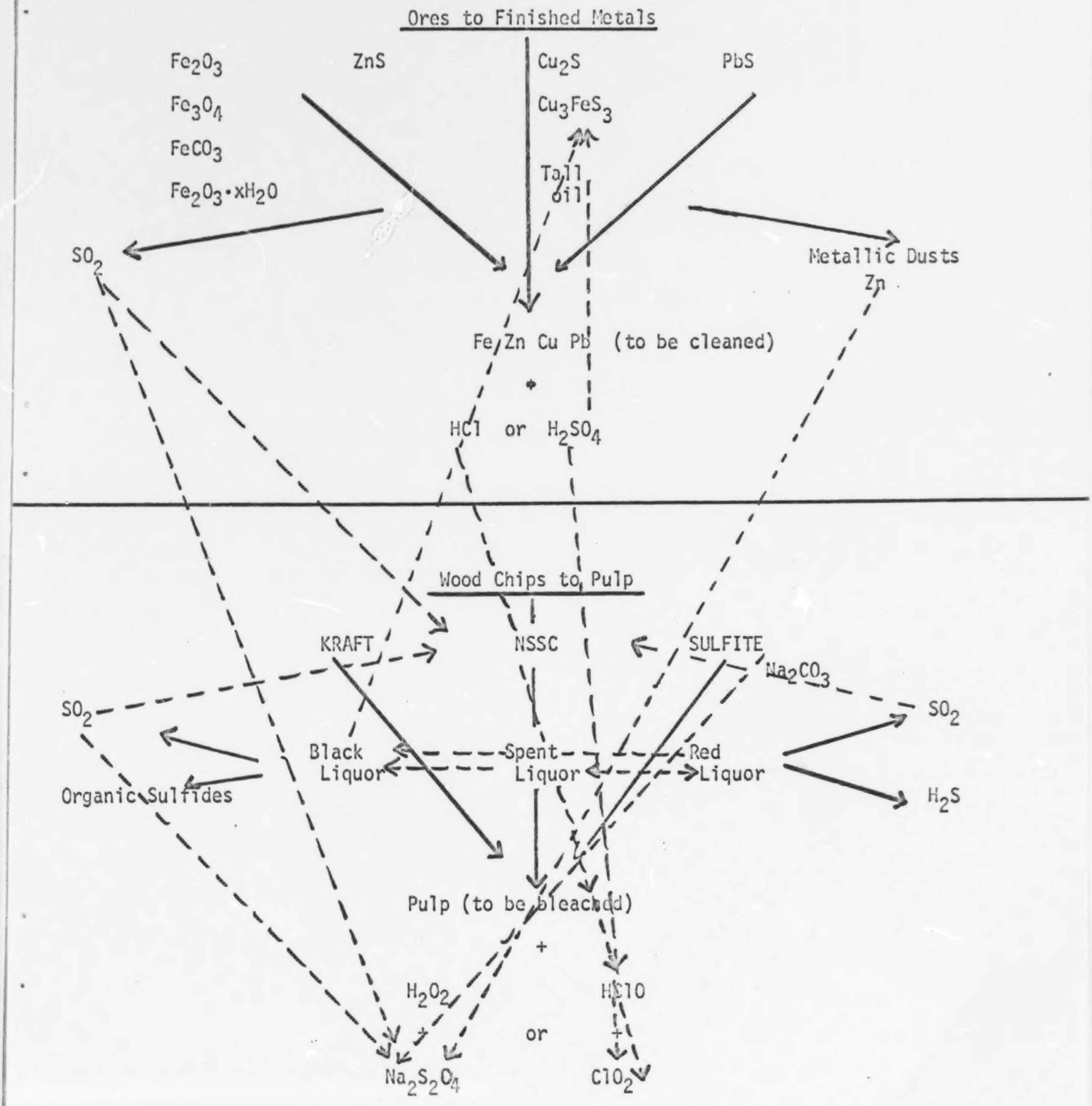
SYMBIO is the routine which searches for industrial processes which use, as inputs, polluting emissions from another industry's output. The routine can be used in three different ways: to show the use of a by-product within one process, within two processes of one industry, or between two processes of two industries. For example, in the paper and pulp field, there is one pulping process, the Kraft process, in which the starting cooking liquor can be made from the recovered spent liquor of that process and also from the spent liquor of a different process.

Then, also, the sulfur dioxide (SO_2) collected from the

FROM POLLUTANT TO RESOURCE

Figure 3-2

(Dotted lines indicate possible uses within these processes.)


Ores to Finished Metals
Fe_2O_3
Fe_3O_4
$FeCO_3$
$Fe_2O_3 \cdot xH_2O$
ZnS
Cu_2S
Cu_3FeS_3
PbS
Tall oil
SO_2
Metallic Dusts
Zn
Fe Zn Cu Pb (to be cleaned)
+
HCl or H_2SO_4
Wood Chips to Pulp
KRAFT
NSSC
SULFITE
Na_2CO_3
SO_2
SO_2
Black Liquor
Spent Liquor
Red Liquor
Organic Sulfides
H_2S
Pulp (to be bleached)
+
H_2O_2
or
HClO
+
+
$Na_2S_2O_4$
ClO_2

stacks of all three pulping processes can be recovered and used as a starting material for the NSSC and S digestors, and also for certain bleach processes. Sodium carbonate which is recovered from the fluidized bed of certain acid sulfite mills can be used in the production of sodium dithionite for pulp bleaching.

The SO_2 for the digestors can also come from the copper, zinc, and lead smelters of the metallurgical field or from the stacks of the auxiliary power boilers used by most pulping mills. Zinc dust can also be recovered and used in a pulp bleach process. Spent pickle liquor from the metal finishing processes is usually either hydrochloric acid (HCl) or sulfuric acid (H_2SO_4). These dilute acids can be recovered and concentrated for use again in both industries: for bleaching of pulp, for metal finishing, and as a leaching agent for low grade copper ores. The sulfuric acid can also be recovered directly from the non-ferrous smelters as a recovery product. Its local use precludes the problem of shipping the heavy acid.

Tall oil which is presently produced from Kraft Black Liquor by conversion with H_2SO_4 can be used in the flotation process of ore separation. Also, the tall oil chemicals are used in many other ways. The turpentine production from Kraft pulping has grown in recent years so that a large number of Kraft pulp producers have initiated their own turpentine purification and fractionalization plants. The sulfite and NSSC producers have found fewer markets for their spent liquors, but to repeat other successful ventures, emphasis might first be placed on research and development of uses and second on the combustion of these liquors for heat content.

CONCOV is the routine which searches the list of pollution abatement devices to find those which potentially may convert a pollutant into a valuable input for a new industry. It operates on the premise that there is a choice of control devices, and that some control techniques may convert pollutants into resources in a particular region. This is especially important in the non-ferrous smelting field where the sulfur dioxide emitted may be collected as sulfur, sulfur dioxide, ammonium sulfate, calcium sulfite and calcium sulfate, and sulfuric acid. It is preferable to avoid the shipping of sulfur as sulfuric acid whenever possible due to its weight. The processes for regeneration of waste pickle liquor also allow the recovery of iron as magnetite, iron oxide, or iron sulphate depending on the recovery process used. Each of these forms of iron has specific uses which may be limited to region.

Kraft pulping emissions include many other sulfur compounds besides SO_2. Separation in the stacks would allow the use of dimethyl sulfide and methyl mercaptan to make dimethyl sulfoxide, an important chemical solvent and reagent, and other sulfur derivatives. All recovery products lessen the cost of pollution control devices and the choice of and design of devices should be done in the context of information offered by EMIS.

Continuing to illustrate possible connections in our illustrative data base, SUBPRO, the third routine, shows processes which may be substituted in order to be less polluting. For example, the ferrous and non-ferrous smelters are large producers of dusts and off-gases. But the government and public outcry over air pollution from these smelters may force changes in this present technology. The copper producers, for example, now have several hydrometallurgical processes in both the developmental and pilot-plant stage which avoid the sulfur dioxide and particulate emissions, and also include the regeneration of starting solutions and the recovery of by-products.

Substitution, however, must be very carefully considered; for a different process may also produce different, but still dangerous, pollutants. Thus a furnace of a pulping mill may burn bark in order to avoid the sulfur dioxide emissions of coal and oil, but increase its particulate emissions while doing so. Similarly, a replacement of the open hearth furnace in iron smelting with the basic oxygen furnace may increase the amount of dust produced. Here though, a gain may come about because a new basic oxygen furnace will have more efficient dust controls than an old open hearth, just because it is new. This routine will also show the pollution control aspect to decisions regarding the closing of old plants. Often, the old plant employs process equipment which must be replaced for greater efficiency in emission control. This decision, however, must be carefully evaluated; for, in the case of old soda pulping plants, it may be more efficient to keep the plant as the soda process does not emit sulfur off-gases.

SUBPRO would consider chemicals as representatives of general groups, thus allowing unusual substitutions not thought of by engineers during the normal communications of their jobs. Under this routine, inputs and outputs would be collected by chemical groups such as acids and bases: strong and weak, and organic and inorganic. Also, general classifications such as reducing agents and oxidizing agents would be included. Thus in the case of waste pickle liquor, it might be feasible to use the ferrous sulfate recovered as a reducing agent in certain chemical processes, if it were available locally.

SHAREC is the routine to share costs of disposal and especially to help those industries with plants too small to afford individual abatement equipment, by creating a pollution control utility with many suppliers. It would include such devices as mobile charcoal beds on tank cars, fixed central waste stations, or shared stack cleaners. In this way, one expensive device could serve many users. This routine would lead to the formation of a central facility for a group of industries with the means to collect and treat. All opportunities for regeneration and recovery will have been identified by the routine SYMBIO, hence this routine is concerned with chemical treatments such as neutralization of acids and bases and incineration, as well as biological treatments. It could also include common power plants for pulping mills, and some of the larger stack cleaning procedures where the economics would warrant the sharing.

Often the addition of a chemical species or a change in pH caused by the waste treatment will cause the appearance of a new chemical by-product. A repass through SYMBIO and FEASPO will identify this new by-product as a possible starting material.

An example of this shared cost approach is a group of small metal finishing plants turning out many tons per year of pickling liquors. Individually, they might not be able to afford the large capital outlays for separate pollution abatement equipment, but together they could support a central waste station. It could originally start as a simple treatment plant, but through the use of SYMBIO and FEASPO, develop into a central facility able to concentrate the acids for reuse and to economically recover and sell the metal salts to other industries in the region.

These first four routines complete a picture of the present possible by-product recovery and reuse within the pulping and metallurgical fields discovered through a preliminary study with the manual version of EMIS. A qualitative demonstration of this is made in Figure 3-3.

This output will then be augmented by TECFOR and HARCOR and a test of its quantitative feasibility, both chemical and economic, will be made by FEASPO.

TECFOR is the routine which updates the elements of the system for projected rather than present technology and gives information concerning increasing or decreasing rates of change of the magnitude of processes in use. For example, there is work at present on new design and equipment for all of the processes discussed in this report. There is also research on the possibilities of replacing these processes with new processes. In many cases this research is completely independent of the pollution control assessment necessary,

EMIS ALTERNATIVE ABATEMENT PROCEDURES
Figure 3-3

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Pulping (Kraft)	SY CO SH	SY			SY	CO		CO	CO	CO
2. Pulping (Sulfite)	SY	SY CO SH			SY	CO		CO		CO
3. Pulping (NSSC)	SY	SY	SY SH		SY	CO		CO		CO
4. Auxiliary Furnace		SY	SY	CO SU SH	SY	CO		CO		CO
5. Bleaching (Dith.)					SH	SH				
6. Bleaching (Chlor.)						SH				
7. Iron and Steel (Smelting)		SY			SY	CO	SY SH	CO		CO
8. Iron and Steel (Pickling)						SY		SY CO SU SH	SY	SH
9. Non-Ferrous Met. (Smelting)		SY			SY	CO		CO	SY SH	CO
10. Non-Ferrous Met. (Finishing)						SY		CO	SY	SY CO SU SH

KEY: SYMBIO - SY, CONCOV - CO, SUBPRO - SU, SHAREC - SH
COLUMN AND ROW HEADINGS ARE IDENTICAL.

but may be used in pollution control. For example, there is a pilot plant using nitric acid for wood pulping, thus eliminating the organic sulfides and sulfur dioxide presently emitted in sulfate/sulfite pulping. The process will have to be studied for the possibility of other new emissions of different pollutants.

Also the copper industry is showing changes relevant to the subject of pollution control: mining techniques now include milling and flotation, and smelting may also change. Elimination of the reverberatory plant would reduce the volume of off-gases to be treated by one-third. This step plus a change in the amount of oxygen used in the smelter would allow a company to comply with strict air pollution codes at a lower cost. (See Journal of Metals, August, 1970, pp. 51-54.)

These inputs of the routine will be augmented as new uses for materials such as fly ash are found. A new use for fly ash in a region where minimal quantities are presently produced would encourage a new industry also producing fly ash to locate there. Here too, will be the innovative new chemistries: in this data base particularly, new sulfur compounds and new uses for the present compounds will be explored.

The inputs of the routine will also be expanded to include new research on the relationship of the earth's natural resources to the land. For instance, the question of the necessity of sulfur and sulfur compounds in the soil as a plant nutrient and soil amendment will be included. New studies show that recycling of sulfur to the earth may be as important to agriculture as is the reforestation of land. (See, for reference, "Potential Plant Nutrient Consumption in North America", Technical Bulletin Number 16, The Sulphur Institute, July, 1969.)

TECFOR will include all projections available showing increase or decrease in consumption of particular commodities and increase or decrease in available resources. In this way the next routine's concern with feasibility will operate with projections meaningful for future planning.

Until this point we have been seeking connections among industries in the illustrative data base without concern for feasibility criteria. The reason for this is that feasibility is a function of abatement policy. Recapturing wastes becomes feasible under a policy prohibiting or restricting their disposal. Under different policies, different practices are feasible. Indeed, the recycling policies of the same company vary in the different states of operation according to what the strictness of regulations determine to be "feasible."

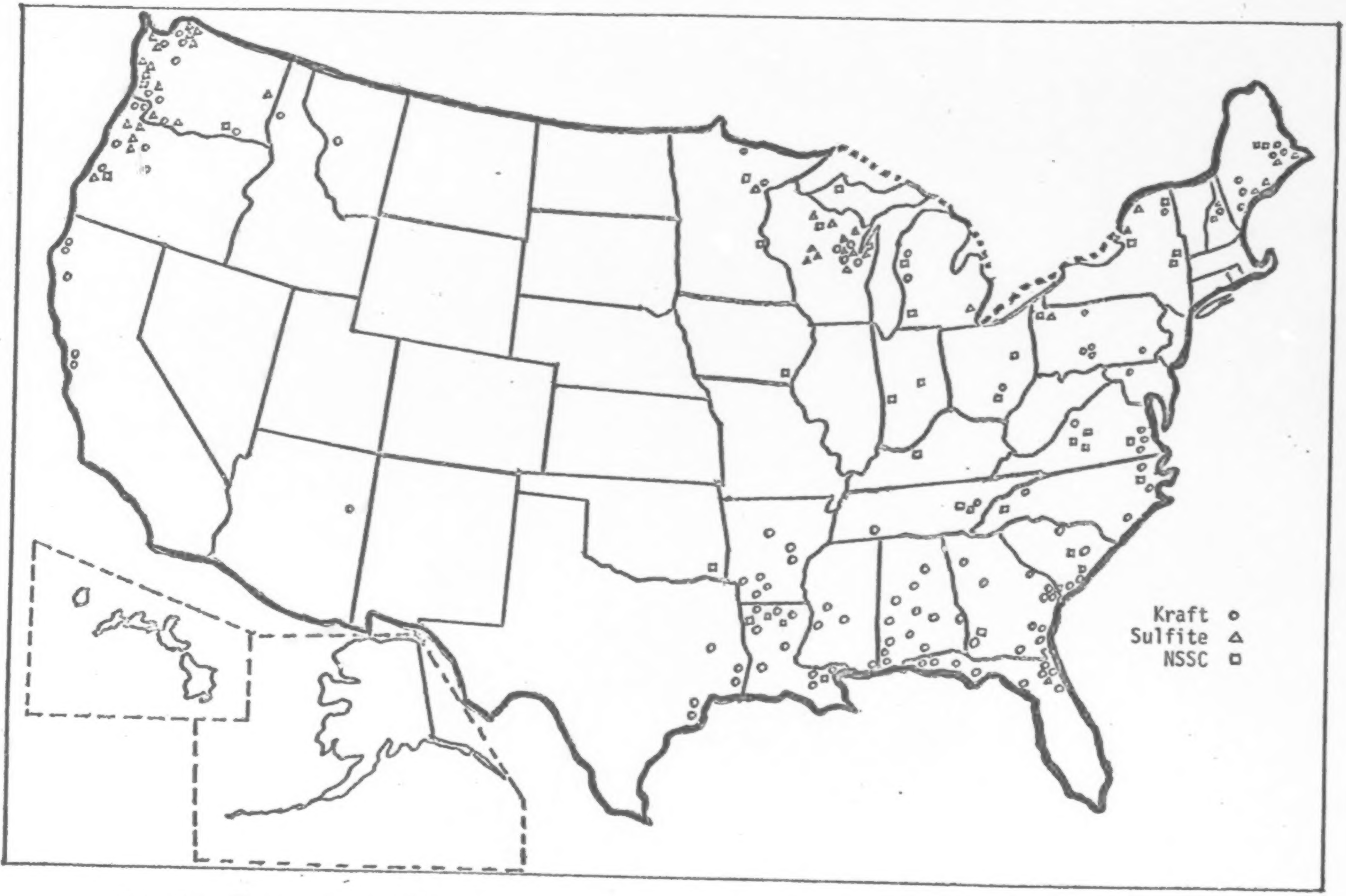
Clearly, however, feasibility is a critical factor and it fits into EMIS as the routine, FEASPO. It can be demonstrated by inputs from the processes already described. FEASPO is the cost calculator for all the other routines. For the pulping field, data would be supplied from all the mills showing: name of plant, type of process used, location, annual production, and amount of spent liquor, both before and after recovery and the amount of air emissions, with chemical analysis, both before and after recovery.

In this example, SYMBIO operates on just the aqueous emission data. Output would include a locational analysis showing the amount of spent liquor from each of the processes in a particular region, the amount of possible use for by-products, and then the amount for mutual use of effluent through cross recovery systems. National output is summarized below and the data for location could be presented by map as in Figure 3-4.

DISTRIBUTION OF SPENT PULPING LIQUOR (1965)

	Kraft Process	Sulfite Process	NSSC Process
Tons of air-dry pulp ($X10^5$)	21.5	2.7	2.9
Tons of spent solids ($X10^5$)	30.0	2.5	not available

Much discussion of the possible by-products of these waste pulping liquors has already been made in many reports and they will not be described in this study. (See for example, Environmental Science and Technology: Vol. 2, No. 9, pp. 676-681.) Certainly in pulping, these markets are limited, and this report will stress instead, effluent cross recovery techniques which can be used on the remaining portions of the waste liquors. The Kraft process can accept pulping effluent from both the sulfite and semi-chemical processes and FEASPO would suggest the economic costs associated with the alternatives. Pulping mills at present mix their various pulps in order to obtain a



Data from Figures 2-1 and 2-2
"Control of Atmospheric Emissions in the
Wood Pulping Industry" , Volume 1, pp. 2-7 +2-8

REGIONAL DISTRIBUTION OF KRAFT, SULFITE AND NSSC
PULP MILLS IN THE U.S.
Figure 3-4

specific end-product, and FEASPO would facilitate the mixing of effluents in order to obtain maximum heat utilization, and recovery of cooking chemicals. In regions where FEASPO showed either the amount of effluent to be too small, or the locations of plants to be too distant, the data would proceed to CONCOV. (See Figure 3-4.)

For the aqueous pulping effluents, CONCOV will show the different techniques, both physical and chemical, including screening and sedimentation centrifuges, freezing, reverse osmosis, ultra-filtration, aeration, biological reactions, and combustion. (See for example, Journal of the Water Pollution Control Federation: Aug., 1970, pp. R279-R289.) FEASPO would then show the costs of each taking into account through HARCOR the low biodegradability of the lignin sulfonates.

This discussion of the various means of collection would lead to an investigation of any possibility of by-product manufacture which might differ from those already collected in SYMBIO. For example, if the air emissions were under discussion the question of the form in which the sulfur should be collected would be raised and also the problem associated with fly ash would be considered. The fly ash produced by the power boilers burning the waste bark has a high sand content and certain collection devices must be used. (See, for example, Journal of Technical Association of the Pulp and Paper Industry: Aug., 1970, pp. 1441-1448.) FEASPO would be available to investigate the cost-accounting necessary to reach an implementation decision. At this level of detail we will be operating a man-machine interactive system in an interactive mode.

SUBPRO shows those processes which can be substituted in order to be less polluting, and it would use FEASPO to test the feasibility of oxidation of the spent liquor from a Kraft mill prior to its introduction into the direct contact evaporator. This is a process change designed to reduce the odorous emissions which accompany the exhaust gases from the recovery unit. (See the Journal of the Air Pollution Control Association: Vol. 20, No. 6, pp. 373-376.) FEASPO would help calculate the costs associated with this process change.

In setting up any central waste treatment plant as previously discussed under SHAREC, FEASPO would define an operable region and the economic cost analysis generated by the collection, recovery and sale of the chemicals involved. It would show the net costs of the plant operating in different modes as a final output.

FEASPO would also lead to the selection of materials for HARCOR to be accomplished for economic reasons as well as chemical. Certainly, there will be materials whose recovery costs are so high, and their uses so limited, that at the present time their own place in the system will be into storage/dumping.

After the inputs from TECFOR, the routine FEASPO will produce a strategy report. This could include a map showing all the industrylocations involved, with their respective processes, and the suggestions for pollution abatement for each. This allows an optimizing procedure to be followed and alternatives arrayed for a decision.

In this illustrative data base we have ignored HARCOR as a routine for simple matching of industries, which is not at issue. What is needed are parameters for considering alternatives. The alternatives for ultimate assimilation or isolation of unusable residual products generated by industry from the environment can utilize several strategies within existing technology. Several HARCOR alternatives will be scanned as methods of assimilation or isolation of unusable industrial wastes.

1. Increased efforts to reduce contamination of surface and ground water resources and the accelerated production of diverse types of relatively untreatable wastes have stimulated interest in deep well injection--a process for permanently storing waste in underground strata. Several major parameters must be considered if the deep well injection method is to be utilized. HARCOR wastes can be considered suitable for deep well injection if:

--They are toxic or otherwise highly objectionable and cannot readily be treated or disposed of in other ways.

--Volume is small enough so that deep well injection is practical because underground storage space is a valuable natural resource and should not be carelessly used (intake rates range from 100-300 gpm).

--The chemical and physical characteristics allow injection with orwithout prior conditioning with reasonable assurance that the injection well will not be rapidly and permanently plugged during operation.

Site suitability depends on regional and local geology and hydrology. Characteristics of a suitable injection well site are an injection horizon with sufficient porosity, permeability and areal extent to act as a liquid storage reservoir at safe injection pressures; an injection horizon that is definitely below the level of freshwater circulation; and definitely confined by strata that are impermeable. Injection horizons with the latter characteristics are located in thick sequences of sedimentary rock usually containing sandstones, limestones, or dolomites. Confining strata must overlie or underlie the injection horizon to prevent vertical escape of injected wastes. Adequate confining beds contain unfractured shale, clay, silt, anhydrite, gypsum, marl, and bentonite. Other major site factors to be considered would include the rate of lateral movement of injected wastes and local natural incidence of earthquakes.

The deep well injection technique could also be utilized as a potential solution to some air pollution problems. Toxic or otherwise obnoxious fumes could be injected into underground storage reservoirs.

Where this technique is a feasible method of HARCOR disposal, experts from the oil and gas drilling industry will be consulted to examine and delineate all parameters to ensure the safe operation of deep well injection methods.

2. The handling and disposal of digested wastewater sludge is an acute problem for treatment plants. Where there is joint use by the municipal and industrial sectors or where the industry has its own waste treatment facilities, a technique does exist which

affords a method of assimilating or isolating HARCOR sludge materials from the environment. This technique utilizes a pipeline transport of digested sludge slurry or a way of transporting many kinds of solids suspended in a liquid medium in pipes. Transport distances may range from as short as one mile or less to as long as 100 to 200 miles. In light of this range, this dumping strategy can take advantage of local and regional land use problems, subsurface geological and hydrological characteristics as well as topographic features.

The assimilation of HARCOR sludge slurries by the environment is especially valid where there is a need for land reclamation. Pipe transported sludge slurries can be used efficiently on strip mine areas and other exposed land such as road building construction or similar operations where organic layers are removed. Digested sludge slurries are in effect a low grade topsoil providing moisture and nutrients. The slurry dewaters by percolation and evaporation to form cracks and crevices to serve as excellent germination sites for grass, legumes, tree seedlings and seeds. Sludge used on strip mine overburden for reclamation and revegetation is especially beneficial in water pollution control as erosion and acid water production generally ceases after reclamation. Drying and even dry sludge resists erosion and unpredictable movement and therefore, no hazard to public health or convenience would be expected as long as sensible precautions are taken to place and retain the sludge where it is wanted for land reclamation purposes.

A dumping strategy of pipeline transport of digested sludge slurry can be an economical and effective means of land restoration as well as a means of eliminating the pollution effects created by sludge from the environment.

A pipeline transport technique could conceivably be utilized by industry as a dumping strategy method for disposal of HARCOR wastes which do not have properties appropriate for land reclamation. The technique enables an industry to transport its waste a considerable distance from its source. This ability to pipe HARCOR materials suspended in a liquid medium to a remote site for disposal provides the industry with the advantage of a wider choice of alternative site disposal areas. For example, it is feasible within existing technology to transport solids in a liquid medium up to a 200 mile distance. A firm therefore has an opportunity to select alternative disposal sites within a possible area of 160,000 square miles which meet geological and hydrological criteria for HARCOR land fills. In the case of unusable toxic HARCOR materials, an opportunity exists to use the deep well injection technique in conjunction with the pipe transport technique. Materials in suspension could be piped to a safe land fill or storage site where the suspended materials are dewatered. The liquid HARCOR suspension remaining could then be collected and pipe transported for injection into an appropriate injection horizon colocated with the land fill or storage site for HARCOR solids.

3. In recent years HARCOR sludge materials have been disposed of in coastal waters. This method has been utilized without full

consideration of the ecological balance of the ocean environment and needs to be reevaluated. Disposal sites have produced high concentrations of toxic heavy metals such as chromium, lead, copper, etc. These concentrations have greatly modified biological processes in the sediments, thus inhibiting the rate of sludge decomposition. Oxygen content of bottom waters has also been greatly reduced by this disposal method, causing a detrimental effect upon marine organisms.

In order to fully understand the ramifications of ocean disposal and to optimally utilize this resource for HARCOR disposal sites requires several vital parameters to be delineated in order to place constraints upon ocean use as a dumping strategy. These parameters would include the rate of movement and spread of sludge; the rate of decomposition; and the amount of sludge accumulated in an affected area. This dumping strategy should not be used for HARCOR materials until these questions are answered on the physical and chemical parameters of sludge in an ocean environment. Factual data on movement, decomposition, and accumulation would provide guidelines for reaching an ecological balance. To maintain an environment without serious degradation requires the rate of supply of pollutant to be less than the rate of decomposition and transport of pollutant away from the disposal area. In this manner, a determination can be made if ocean disposal of HARCOR wastes is acceptable.

4. Many industries which produce HARCOR by-products are located in areas where the local and regional environment cannot sus-

tain dumping strategies as previously outlined which are dependent upon specific ecological characteristics. Initial industry location may have been dominated by labor force, materials, transportation network availability, etc., without proper consideration of waste disposal problems and their ecological impact. Recent public environmental awareness as well as new governmental regulations requiring pollution control procedures will either cause many firms to relocate where their HARCOR by-products can be safely assimilated by the environment, or many firms will have to proceed with concentrating their HARCOR materials and using a sterile storage technique to isolate materials from the environment.

The Atomic Energy Commission and the various National Laboratories have much experience in isolating radioactive materials and their technology could be utilized by industries needing expertise in the sterile storage of HARCOR by-products.

The quality of the environment may one day carry as much weight as labor supply, materials availability, transportation networks, etc., in future industrial site locations. Ideally, industries which produce HARCOR by-products will locate where these materials can be assimilated by the environment without a degradative effect, e.g. subsurface geology can sustain an injection well technique or subsurface and surficial geology and hydrology enables pipe transport and/or landfill techniques to be utilized. Future industrial planning procedures which include ecological criteria as guidelines in site location will enable HARCOR dumping strategies to be utilized in order to assimilate or isolate HARCOR by-products from the environment.

In going through the illustrative data base and HARCOR it should be clear that the amount of information needed and the number of calculations are both substantial. Because of this difficulty, possible alternatives are rarely sought in industrial practice. With the motivation for pollution reduction, however, the breadth of scanning for alternatives will be greatly increased. EMIS, in its batch processing modes with systematic questioning of the data base, will make breadth possible and in its man-machine interactive modes, it will make depth of analysis practical.

Chapter 4 Alternative Contexts

1. Point Source Regulation--1970's

In February, 1969, the first set of air quality criteria covering sulfur oxides and particulates was issued by the National Air Pollution Control Administration. The next group to be established included carbon monoxide, hydrocarbons, and photochemical oxidants. In 1971, the nitrogen oxides, lead, fluorides, and polynuclear organic compounds are candidates for inclusion. Possible additional polluting chemicals for future attention are from the very comprehensive study of twenty-seven classes of pollutants completed by the Litton Industries' Environmental Systems Division in 1969, in which the effects, sources, abatement procedures, methods of analysis, and the economics were studied.

At the same time, incorporating the assumption that there are more sources of emissions where populations are concentrated, Air Quality Control Regions (AQCR) were set up based on the Standard Metropolitan Statistical Areas (SMSA). "The National Emission Standards Study" published in the spring of 1970, includes the industry sources and costs for particulate and sulfur dioxide control in the SMSA's in effect on

May 1, 1967. As of November 5, 1970, seventy-two AQCR's will have been designated. These regions incorporate the largest and most polluted urban communities in the country including all fifty states, the District of Columbia, Puerto Rico, and the Virgin Islands. Under the terms of the 1967 amendment to the "Clean Air Act of 1963", each state is bound to set up and enforce appropriate air quality standards for its areas included in these Air Quality Control Regions.

Meeting these standards through point source regulations has the effect of encouraging individual plant collection without stressing recovery and re-use. In this way, each company must plan for its own pollution abatement procedures and costs without the possible help of a neighboring compatible company as EMIS will indicate. There is no advantage to be gained from a company's location in a particular region where either other similar plants are located that could use the sharing techniques of SHAREC and SYMBIO, or other plants that could fit into the computer techniques of SYMBIO, CONCOV, SHAREC, and HARCOR. That is to say, there is no emphasis put on re-use and recycling, sharing of waste treatment centers, or on possible dumping strategies, and defining regions to encourage these practices. The regulations and regions, instead, stress mere collection as the method of solving the problem.

Also, and perhaps more importantly, these regulations do not adequately allow for future economic expansion. For example, the power plants are the leading producer of sulfur oxides, and their future growth must be considered. The collection devices presently in use and in study for SO_2 collection will be from 90 to 95 percent efficient. This means that an 800 megawatt plant burning coal with a 3 percent sulfur content can produce either 750 tons of sulfuric acid a day or 180 tons of sulfur a day through collection, and still release 18 or more tons of sulfur dioxide a day from its stacks. Clearly the second 800 megawatt plant put in to alleviate the power shortage will also release 18 or more tons of sulfur dioxide a day, even though it may be using the most efficient collection device available. Add to this, increasing SO_2 from other sources and some regions can have high absolute amounts of SO_2 in the ambient air, even though single sources have been abated. As the present non-degradation standards are enforced, future expansion may have to curtail its rate of increase in order not to violate these regulations. It will prove difficult to reduce the amount of today's pollutants and still plan for future expansion. Even the conversion to breeder reactors, expected to reduce SO_2, is not without consequences elsewhere in the environment that is heat sensitive.

The cost to the government will also increase as a regulation at the source strategy is followed, for government assistance to industry for reducing the cost of controlling air pollution can amount to as much as 59 percent of the actual cost. This assistance comes through the federal corporate income tax depreciation allowances, investment credits, Small Business Administration loans, Economic Development Administration aid, and state tax laws. (For more details, see: "Government/Industry Cost Sharing for Air Pollution Control" by R.D. Wilson and D.W. Minnote, Journal of the Air Pollution Control

Association: Vol. 19, No. 10, Oct., 1969, pp. 761-766.

The point source regulation must be augmented, and it can be set in the context of alternative strategies by EMIS. This addition will allow for pollution control with the decreased costs made possible by maximum recovery and re-use, and still continue future economic growth.

2. The Regional Context--1975

The present Air Quality Control Regions represent those areas of the country in which the states are setting and enforcing air quality standards. This regional approach shows the same problems discussed in the previous section: namely, the emphasis on collection without re-use, and the lack of planning for national expansion.

There is still another problem. These regulations are not strongly effective in the high polluting industries which are not concentrated in the AQCR's. Data on the percentages of these industries in the presently accepted AQCR's is not available, but the "National Emission Standards Study" published in March, 1970, includes the percentages in the first fifty-seven proposed AQCR's. These are shown in Table 4-1.

DISTRIBUTION OF PLANTS
Table 4-1.

		Percent in the first fifty-seven AQCR's	Percent in SMSA's
PULPING:	Kraft	7	25
	Sulfite	6	15
IRON AND STEEL:	Blast Furnaces	55	97
	Steel Plants	57	86
NON-FERROUS SMELTERS:	Copper	16	21
	Lead and Zinc	19	38

Data showing the percentages in the heavily populated 85 SMSA's is also included to show the effect of adding more urban areas to the AQCR's. Certainly this addition will help the iron and steel industry, but it doesn't greatly aid the percentages for pulping and the non-ferrous smelters. The non-ferrous smelters are second only to the steam electric-power plants in the generation of sulfur oxides.

The routines of EMIS can be helpful in drawing regional boundaries to alleviate this problem of exclusion of producers. The first four routines will search out the possibilities for combinations, and FEASPO will show the economic implications. Certainly, the boundaries for different routines such as SYMBIO and SHAREC will differ, but they will be based on the number and kinds of industries present and be independent of the population. With EMIS, regions would have functional definitions based on feasible networks of industries rather than on fixed geographic entities. By 1975, we could have definitions of regions which would be useful for industrial expansion at the end of the decade. Given the lead time for new construction, some plants now on the drawing boards could be encouraged to co-locate in an industrial network in a region.

The formation of a region can be shown by data from the study, "Control of Atmospheric Emissions in the Wood Pulping Industry", contract no. CPA 22-69-18, produced by Environmental Engineering, Inc. and J.E. Sirrine Company, March 15, 1970. This is an exceptionally comprehensive study which shows data for mills by state and by town.

In this report a study of the possible use of sulfur collected from the flue gases of the auxiliary furnaces as a makeup chemical for the cooking processes was made. This data from a national standpoint is shown below.

INDUSTRY-WIDE DATA ON MAKEUP SULFUR REQUIRED VERSUS
SULFUR AVAILABLE FROM POWER BOILERS
Table 4-2

Process	Sulfur Required - Tons	
Kraft	315,900	
NSSC	105,000	
Sulfite without Recovery	218,700	
Sulfite with Recovery	17,800	
	657,400	TOTAL
Potential Sulfur Available	291,327	

Since in the pulping field there are so many variables on type of wood species available, process and equipment used, and product being made; each mill must be considered individually. For example: the Kraft process requires a range of fuel from 386 pounds/air-dried ton of pulp produced (ADT) to 1180 pounds/ADT. If the coal has a sulfur content of two percent, this shows a potential sulfur loss of 7.7 pounds to 23.6 pounds/ADT. The NSSC process requires from 1192 to 1550 pounds/ADT which gives a potential sulfur loss of 23.8 pounds to 31 pounds/ADT; and the Sulfite process requires from 507 pounds to 1630 pounds/ADT giving a potential sulfur loss of 10.1 pounds to 32.6 pounds/ADT.

In each of these cases this potential sulfur loss which shows the amount of sulfur which could be recovered from the boiler flue gases is less than the makeup requirement for the specified process. This requirement is shown in Table 4-3 below.

SUGGESTED VALUES FOR SULFUR MAKEUP--Pounds per ton AD PULP
Table 4-3

Kraft	NSSC	Sulfite	
	Without Recovery	Without Recovery	With
26	60	243	51

It must be noted that this amount of sulfur which could be recovered from the boiler flue gases does not include the amount of sulfur which could possibly be collected from the pulping processes themselves. These data are examined in the report and the number of pounds of sulfur dioxide/ADT can range as high as several hundred pounds, depending on the pulping process, the recovery method, and the equipment used. Also, each mill would have to include data on the sulfur oxides produced by its other operations including the bleaching processes and possible by-product processes. This would then show a total for the mill of the potential recoverable sulfur and its sulfur needs for pulping.

All of this data from each mill would be useful in describing a region for pollution control. It shows that the amount of sulfur for makeup varies with the pulping process, and the amount of possible recoverable sulfur varies with each mill, so that the individual mill's materials flow for sulfur can be either positive or negative. The region could then control this flow by a central distribution system so that the pollution abatement procedures for sulfur oxides could be aided by the economics of the region.

The next step would be to include all the other producers of sulfur oxides in the area and also all the potential users of sulfur and sulfur compounds. For example, the other industries studied in this contract were the non-ferrous smelters and the iron and steel producers. There is a very comprehensive report on the first, "Systems Study for Control of Emissions Primary Nonferrous Smelting Industry", (Contract PH 86-65-85) by Arthur G. McKee & Co., published in June, 1969. This includes data on the sulfur oxides emitted by this industry by location and also surveys the possible markets in the area for the potential products from the recovered sulfur oxides. The data on the emissions shown below is from P. VII a-3.

SUMMARY OF SULFUR OXIDE
GENERATION AND RECOVERY*
Table 4-4

	Sulfur equivalent, tons per year		
	Generated	Recovered	Percent Recovered
Copper smelters:	1,815,900	344,200	19.0
Zinc smelters:	782,700	461,600	59.0
Lead smelters:	178,700	47,100	26.6
All eastern smelters	352,400	302,500	85.8
All western smelters	2,424,900	550,400	22.7
	2,777,300	852,900	30.7

*The figures given here represent approximate annual rates in the first half of 1969.

There is also a very comprehensive report on the iron and steel producers: "A Systems Analysis Study of the Integrated Iron and Steel Industry" by J. Varga, Jr., et al of Battelle Memorial Institute, (Contract No. PH 22-68-65), published on May 15, 1969. Their data showing the sulfur emissions is reproduced below from p. V-64.

ESTIMATED SUMMARY OF SULFUR BALANCE
FOR THE U.S. IRON AND STEEL INDUSTRY (1967)
Table 4-5

Item	Amount, Million NT	Estimated Aver. Sulfur Content Percent	Total Sulfur Content, NT
Blast Furnace Slag	30.0	1.50	450,000
Raw Steel and Scrap	131.7	0.03	39,000
Steelmaking Slag	13.6	0.10	14,000
Fuels			374,000
Possible loss from Slag			68,000
Unaccounted for			10,000
		TOTAL	955,000

The data from Tables 4-2, 4-4, and 4-5 can be combined to give an estimate of the sulfur available from the two metallurgical fields and the pulping auxiliary furnaces. The value for an average year is over 4,000,000 tons of available sulfur. This shows the national picture, but the data is available by individual company to fit into EMIS along with all the other industries also emitting sulfur oxides including the pulping mills themselves. Next must be added all the producers of sulfur by the Frasch process and the recovery processes. EMIS can then operate on all of this data to give a distribution of the potential uses in the region. The region can then be defined as a network of interactions, and policy set within the context of each region's economic and pollution control potential. At that point opportunities for regulation at the source can be better identified.

3. The National Strategy--1980's and Beyond

Certainly, a regional strategy is superior to just a point source view; the number of solutions within one process is small, the number of solutions within an industry is larger and the number of solutions within a region is still larger. However, drawing new regional boundaries by the computer routines of EMIS does not solve all the problems inherent in the regional approach. It will change the emphasis on collection without re-use, it will help in planning for future expansion, and it will be more effective on the high polluting industries which are not yet located in the AQCR's.

The EMIS-oriented regional approach will not solve the problem of the future growth which will change the regions. Projections can be made to estimate the amount of future growth, and they certainly do exist in the three major industries studied, but it is more difficult to estimate the specific location of this future growth, and it is the specific location which is important for EMIS. The regions will have to constantly be updated, and it is this requirement which shows the advantage of a national picture as more than a regional aggregate.

A national strategy will constantly update the regions to give a complete analysis at any given time in the future. It is the only way in which a complete ecological model of closed cycles can be included. Thus the previous discussion on the sulfur oxides should include the distribution of sulfur to the ground for agricultural purposes, the reforestation of the land, and an appropriate discussion of the areas to be mined and those not to be mined. Also, the utilization of scrap metals and waste paper must be included. Wherever possible it is preferable to recycle these materials rather than exploit virgin materials. All of these decisions must be made in a national framework. With EMIS a truly national ecological model of the use of natural resources and the control of pollutants will have supporting information. Considering that in the 1980's and beyond there will be a renewal of our industrial base through growth and amortization of old facilities, a new departure may well be in order. If we can prevent the next generation's rebuilding program from repeating our errors through a recognition of alternatives and if the pressure on resources mounts, industrial location in the 1980's will be greatly affected by the desire to close ecological cycles.

At that time, a national approach will be able to include such features as national zoning where good cleanout air corridors can be reserved for industrial processes which have no viable re-use possibility. Special lands which meet HARCOR criteria for dumping strategies might be set aside for future waste disposal. A national land use policy and an allocation strategy would require the kinds of information and alternatives which EMIS generates. At some point, government intervention will be too restrictive, violating the values which motivate action. However, up until that point, the intervention can be supportive and well informed.

Certainly, to encourage the coexistence of particular industries in industrial park design and location in order to close ecological cycles need not be too government intrusive. Indeed, the payoff to industry should more than make up the restrictions imposed to secure a clean environment while expanding industrial capacity. Government, even today, affects the location of industrial parks by granting dollars for utilities and facilities. If the criteria of re-use, or substitution, or shared disposal were part of the allocation decision, we would be making strides toward a fundamental resolution of the problem of the coexistence of nature and industry. The government's responsibility toward the environment is to help the private sector behave in a socially acceptable manner. The willingness has appeared on all sides; now a program based on good information for choosing alternatives is needed. [illegible] broadens the horizons and suggests alternatives which are [illegible] by other means and which have a potentially higher [illegible] than point source restrictions. As the 1970's give way to the 1980's, the need for alternatives will be established by the pressure of events. It would be advantageous to anticipate those events before the costs of reform mount and tolerating environmental degradation is the only economically feasible alternative.

Chapter 5 One Dozen Reasons Why EMIS Won't Work

Present policy has been the object of criticism in this report and it is now time to turn to reasons why the Ecosystem of Machines Information System itself will not work. In our many discussions with supporters and critics we garnered many objections which should be answered. We invited the critics to throw rocks, and they did. The attacks were very useful and deeply affected the system design, to overcome the objections raised. However, not all the objections came within the system itself, but rather in how the system would be used after it was built. For this reason our discussion must once again broaden to the larger issues. The criticisms ranged from alleged impossibility to collect the data needed, to the problem of getting different competitors to take cooperative behavior. In this chapter we make a sincere attempt to answer and anticipate sceptical readers who feel that the simplicity and formality of the conception does not conform to the complexity of the real world.

Most of the objections to EMIS can be encompassed in twelve main criticisms which can be classified into problems associated with Information, Structure, Costs, and Competing Alternatives.

Information Objections

1. "One major problem is that firms, in their cost accounting, do not take social costs into account, for the cost of polluting is social rather than individual. There is, therefore, no way of the firm determining how much it has to charge itself for the environmental damage it may do."

While this failure of the marketplace to signal social costs may be accurate, the new values which are currently being implemented to create a clean environment, have radically altered the public demands in a short time. Quality programs are now being enforced, citizen suits are growing, and industry itself is feeling the need to make changes in the policy of writing off the environment as a free cost. Therefore, the costs are coming to be clearer with each passing day. The rash of activities by the different levels of government, citizens' organizations, and industry are pushing the issue to force the recognition that there are environmental costs to be borne.

Industry is becoming well aware of the costs. Therefore, even though the marketplace has failed to signal social costs, other elements in the social system are making the costs very real.

2. "EMIS requires so much data that it would be either impossible to get it or the price of getting it would exceed the value of the system."

When we first started designing the system, this criticism seemed all too true. However, we have uncovered sources of data used for other purposes which can be readily adapted to EMIS. As mentioned in Chapter Two, there are existing and near-existing data sources. We have a substantial start with the Directory of Chemical Producers, which collects data that is needed for EMIS. The shortcomings of the data here can be greatly aided by extrapolating the data from known processes. While this form of data will have to be expanded for a comprehensive and detailed EMIS, it will contribute to a useful early version for limited application. Data is the major limit on the scope and feasibility of EMIS and we can usefully work within the limits until time removes them.

As a further contribution to the solution of the problem, we have designed an interactive mode for the man-machine system so that details of either current data or complex special cost calculations can be done without building an entire data base. This way, the entire data base does not have to be manipulated at one time, but selected problems could be dealt with at a level where detailed information was excessive for batch mode of operation, but suitable for a man to provide.

In addition to this keeping of data at levels which can use the experience of a man, we can have the man directly communicate with an industry which might benefit from a network approach and the industries in the network could then provide the confidential data which they or the staff person could check out for highly detailed chemical and cost analysis. This last approach might also lead to a subscription service in which industries could contribute proprietary data confidentially and matches could be made by the bonded operator of the subscription service. Industries would be notified of possible matches to explore as they saw fit.

If we add this institutional capability and consider the growing government data collections, the data problem appears soluble over time and an effort worth making because the availability of new forms of data greatly increases the abatement options open to both government and industry.

During the course of the study we have become acutely aware that the abatement strategy which can be taken is highly dependent on the data available. It seems to be very short term reasoning to base action on available data when gathering new data sets would greatly increase the options open to governments. The resulting excessive data in some instances and insufficient data in others hampers the selection of alternatives. For example, water quality data is often collected with treatment in mind, but if recycling were to be the strategy, then different data would be needed.

There are many ways to collect data for water quality.

1.) Water Quality Constituents for the Biologist
    - Temperature
    - Dissolved Oxygen
    - pH
    - Light
    - Flow
    - Silt
    - Oil
    - Major Nutrients
    - Micro Nutrients
    - Toxic Substances

2.) Water Quality Constituents for the Industrial Sanitary Engineers for cooperative program with municipality
    - Flow
    - Suspended Solids
    - BOD

(Cost includes three constituents above plus collection)

3.) Water Quality Constituents for the plant engineer
    a.) as in No. 2
    b.) a complete analysis including
        1. materials flow chart
        2. chemical analysis
        3. sample analysis with DO, BOD, pH, temperature, taste, odor, settleable solids, total dissolved solids

From the point of view of improving options, we should encourage collection of data as in the third set. EMIS gives the capacity to manipulate such an array of data and finds ways of using it to good advantage. The momentum of events has put us well on our way to this goal and EMIS can make the data requirements clearer and set priorities for collection.

3. "If we place EMIS in the Federal government it will soon support a vast bureacracy and fall into the trap of overcentralization in dealing with a problem that has many decentralized aspects."

While this theory of bureacracy is sometimes honored by practice, it arises more from peeve than from good predictive rules. However, even if such an ultimate fate were previewed, it is clear that there are ways to avoid it. For highly technical projects, such as atomic energy development, the government has established National Laboratories which are relieved of many of the constraints of a Federal bureaucracy. Skills already exist which would make EMIS possible to carry out, even without additional personnel. Wherever EMIS would find a home, be it in a National Laboratory or some new agency like the Environmental Protection Agency, there are sufficient feedback checks in the design to know when it is acting like a monster rather than as a policy tool to help systematically scan abatement alternatives. Since the output is not vague, but consists of actual matches, the number of failures would not have to be large before the error could be fixed. In other words, EMIS gives sufficiently good feedback on its own performance that even if it were set in the worst circumstances, failure could be detected and corrected.

Structural Objections

4. "It is clear that recovery and recycling are good ideas, but in practice the materials are owned by different companies and to encourage this much cooperation is unrealistic. In an economic structure of competition, cooperative behavior and information sharing are kept to a minimum."

We would argue that EMIS is consistent with that minimum and where it is not, the government may want to consider some incentives or disincentives to encourage cooperation. There is already great precedence, as among the fly ash producers, for cooperative behavior to find new markets and do industry-wide research. This precedence bodes well for EMIS for there are a great number of examples of trade organizations facilitating cooperation.

At some level of cooperation, however, companies can be held liable for restraint of trade. A policy of allowing conglomerates or other corporate devices for the purposes of encouraging pollution abatement may be more in the present social interest than restriction on cooperation. The costs passed on to the consumer for pollution abatement may exceed those brought on by cooperation in some form of conglomerate relations. In these instances, the Federal Trade Commission may want to investigate the role it can play. In Japan, where cooperation between government and industry and among industries is much farther advanced than in the United States, we already have examples of corporate liasons based on pollution abatement philosophy.

Some of the best successful examples of recycling in the

United States come from within single companies and this indicates that the structural problem will have to be overcome. But cooperation is not without good precedent, so we believe it can be successfully pursued.

Short of these larger considerations, it is also possible to have a confidential data base which will only indirectly reveal competitive information and only then at the mutual consent of the industries cooperating in the confidential system operated by a third party.

5. "The variation of industrial activity by region and process is almost infinite and the daily changes in market prices both require a decentralized structure."

Extended to its logical conclusion, this criticism would imply that management is impossible in the American economy. Just as we do not ask a centipede which leg he puts out first in order not to paralyze him with concern for theory, so we are loath to say that national companies could not cope with regional variation. The United States has many large corporations which manage to keep abreast of these changes and the same kind of effort which they make would apply to the operators of EMIS. EMIS could work with data gathered from many sources and maintain a highly flexible data base design and analysis routines.

The data storage design could vary according to the amount of variation over time and space and consumer habits. Rapidly changing data could be stored in an easy access mode so that updates could be readily done. Telephone, either automated data read out or human voice communications, could handle highly erratic phenomena and more stable data would be periodically updated.

In the design of the data manipulation we have also provided a format for using the variations and expertise of a skilled operator. The on-line access facilitates recalculations due to variations and allows more intensive examination when necessary.

We have tried in the design of the system to anticipate the objections of the critics we interviewed. This criticism from the point of view of variation seems among the most potent, but by giving flexible updating, on-line access, and a skilled operator we have reduced our concerns about this criticism.

6. "The amount of poisoning and damaging materials released into the environment is often so small that their volume renders them incapable of having enough economic value to make recycling worthwhile."

While it is quite true that the effluents we are trying to prevent from reaching the environment are often small in quantity, that has not prevented clean-up when the will to do so was sufficiently urgent. Instead of waiting for mercury to collect in the food chain, a rapid change of government enforcement made it possible within a matter of months, to solve over 86% of the problem by collecting at places of discharge. Now, EMIS would suggest that the next step is that the small amounts be brought to central collection stations so that the economic value can be achieved. Where the cost of collection may not be a paying proposition, it could be cost reducing. EMIS can identify the small amounts discharged and the FEASPO routine can determine the economics of central collection stations and market potential thereafter.

SHAREC is especially designed to identify common substances which are small in amount but which are difficult to treat or discharge raw. Data for these small amounts is a greater problem. We would probably give priority to data collection in the case of urgent problems and highly toxic substances, without building the entire data base for small producers until the data are available in a less expensive form. This will be the case as the result of state data collection and accumulation of information about polluters. State data sometimes goes into levels of information which would be helpful, even at the outset of our effort.

One limit on small amounts cannot, however, be overcome. For EMIS to work, the pollutants must be collectable and auto exhaust devices which do not rely on collection are outside the scope of EMIS.

Costs Objections

7. "Users of EMIS will rebel against paying the costs of taking its suggestions, for while it is primarily designed to reduce costs of abatement, it will identify possible neglected areas of enforcement and therefore force resources into areas which were not slated for consideration."

While it is true that EMIS will open up new areas for attention and therefore encourage changes in resource allocation pattern, this is not necessarily a social disadvantage. Where the hardships on particular industries have consequences which are deleterious and the government wants to subsidize costs, there is adequate precedent for that as well. Tax relief through write-offs and other means helps share the costs. Perhaps governmental renting of pilot conversion processes until they are checked out would lessen the pain of trying out new opportunities. A program of innovational rent would probably be still cheaper than the closing down of polluting plants and the loss of jobs and increases in unemployment benefits. Showing old plants how to join a network may be far cheaper than the costs which would be borne in the difficult transition. Central collection of wastes and resale in cases where individual producers cannot afford abatement equipment may be the only alternative other than closing down. In these cases, the increased costs resulting from EMIS suggestions will be easier to bear. While it might be felt that marginal producers should be shut down anyway, in some industries the cost of abatement is simply too large a fraction of total investment, even in a successful firm.

8. "A clean environment costs too much money and EMIS will encourage expenditures."

The public has indicated, through the representative process, that it is willing to pay some part of the next round of income for cleaning up. The political process will work to determine the ultimate price the society is willing to pay. EMIS is responsive to the demand and it cannot exceed what the political process will ultimately call the top of expenditures. EMIS is an information system. The consequences people draw from this information is not built into the system. That comes from forces on the outside.

Competing Alternatives Objections

9. "Among the most attractive competing alternatives to EMIS is the present practice of buying virgin materials. The lines of supply and communications are already set up and the force of habit is a strong motivation for behavior."

Indeed, this and the other competing alternatives are in some way the most serious of the dozen objections. If it is easier to buy virgin materials, procurement officers will operate in that fashion. In this case, as in all of the objections based on present practice, the will to change is necessary before EMIS will become effective. A change in our natural resource allocation policy may be called for, even in the next decade as the result of shortages which the marketplace cannot provide. In those cases, the motivation to change will be acute with or without EMIS. EMIS gives information to help that policy be formulated. In the cases where long range planning is needed to identify shortages before they occur, the sense of urgency will be provided by outside forces. These forces become input parameters for TECFOR and FEASPO, for as shortages are anticipated, the feasibility of new allocation patterns increases. There is room in the EMIS design to accommodate these changes.

10. "There is a possibility of avoiding restrictions by simply moving to those states, and even those countries, where the restrictions are less stringent. Even today the same companies recycle and dump, either treated or untreated, according to the variation in ordinances."

There will always be variations in willingness to pay for a clean environment. Present strategy of point source restrictions and regional quality zones allows for these variations. However, the willingness to be dirty comes often not from competitive economic advantage, but from a paucity of known alternatives. If states with low relative standards want to be the unclean workshops of the nation, they should at least know that the possibility of an industrial network exists which provides both jobs and pollution control. Clearly it is up to the choice of a region, unless its choice impinges on its neighbors, to set the level of quality of the environment desired. EMIS does not question this right, it only provides information such that the decision is made intelligently, rather than on the basis of narrowed alternatives.

11. "The capacity to recycle and save resources won't work because present abatement strategy gives most funds for treatment and these funds are readily available. Re-use will lose out to subsidized treatment programs."

Treatment is one alternative of EMIS. However, treatment may be the enemy of better policies. At some point we will have so much treatment that it will be a problem itself. There is some cut-off point when re-use is better than treatment and dumping. It will take a change in Federal policy and state policy to make the other alternatives clearer and as available as treatment. EMIS poses those alternatives but the inertia of present programs will weigh heavy in the pattern of future behavior. EMIS is restricted in that it gives only information to show alternatives; it cannot generate the will to follow through to new programs. It offers consciousness, not coercion.

12. "The most successful competing alternative is inertia."

Alas, this criticism speaks loudly, except that behavior of the public, government and industry has already changed a great deal. Few analysts would have predicted the rapid change that has come over America, and some parts of Europe, in the last two years. It will take political clout to change the pattern of inertia, but the change has begun and the results so far have surprised even those who make the competing alternatives from past behavior a key reason for objecting to EMIS.

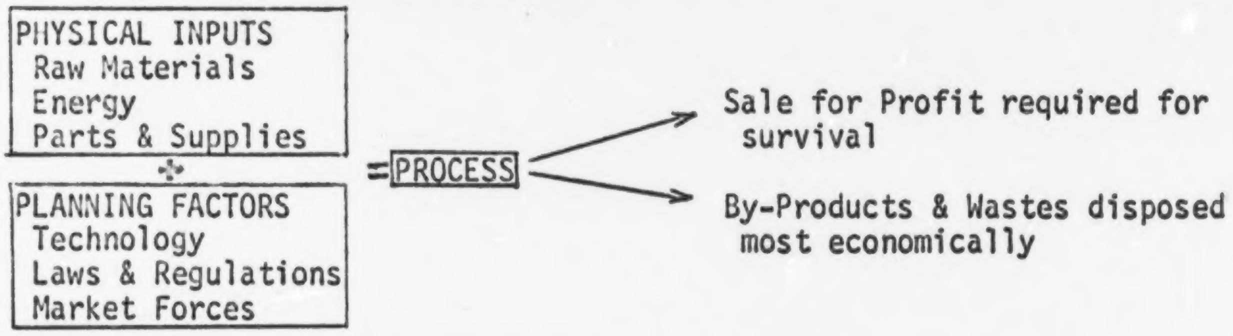
We have discussed one dozen pros and cons of building and implementing EMIS. Of course the reader must make up his own mind, but the rapid changes which are occurring give encouragement to the fact that exploration of alternatives is now going on with rapidity. An information system designed to handle the questions which choices of policy require can be made available when the will to use it appears. While this chapter has especially focused on the objections of critics, it has been gratifying to find that in discussions in which we took time to explain the details of how EMIS handles the largeness of the task, we have found more confidence than skepticism.

The reason for the confidence comes perhaps from a recognition that while the discussion thus far has concentrated on the point of view of society and government, it has not left out the individual firm as the object of social policy. The diagram below indicates that the previous discussion could not have taken place without concern for the firm as the central actor in the American economy. In a summary way, the diagram indicates that the firm's planning takes the factors into account which direct EMIS routines and EMIS takes the firm into account as it operates to systematically identify pollution abatement alternatives.

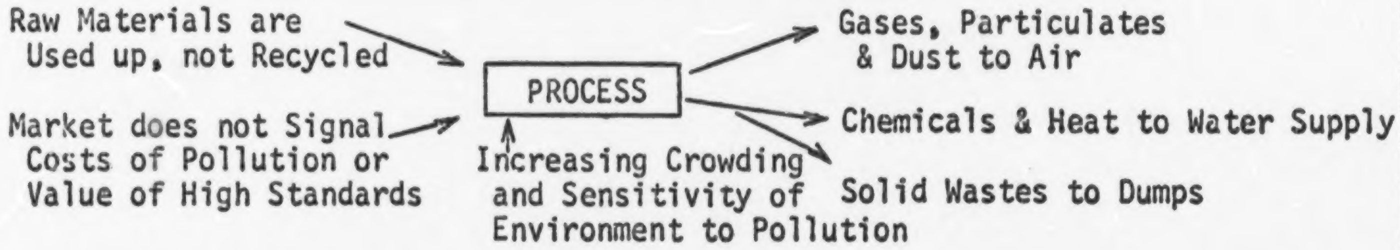
EMIS FROM THE FIRM'S VIEWPOINT

Figure 5-1

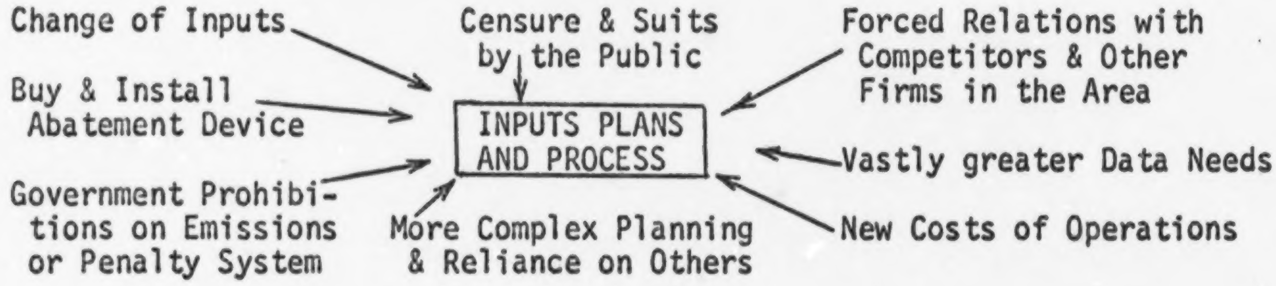
1.Independent Operation of a Firm


PHYSICAL INPUTS
Raw Materials
Energy
Parts & Supplies
+
PLANNING FACTORS
Technology
Laws & Regulations
Market Forces
=PROCESS
Sale for Profit required for survival
By-Products & Wastes disposed most economically

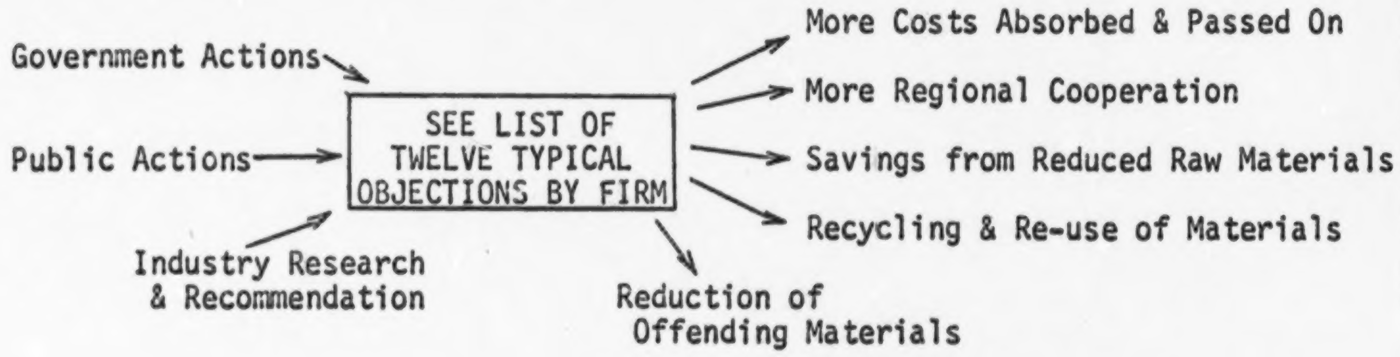
2.Waste and Pollution Accompany Unfettered Enterprise


Raw Materials are Used up, not Recycled
Market does not Signal Costs of Pollution or Value of High Standards
PROCESS
Increasing Crowding and Sensitivity of Environment to Pollution
Gases, Particulates & Dust to Air
Chemicals & Heat to Water Supply
Solid Wastes to Dumps

3.The Firm Faced with Abatement Measures


Change of Inputs
Buy & Install Abatement Device
Government Prohibitions on Emissions or Penalty System
Censure & Suits by the Public
INPUTS PLANS AND PROCESS
More Complex Planning & Reliance on Others
Forced Relations with Competitors & Other Firms in the Area
Vastly greater Data Needs
New Costs of Operations

4.Nudging the Firm into a More Complex System


Government Actions
Public Actions
Industry Research & Recommendation
SEE LIST OF TWELVE TYPICAL OBJECTIONS BY FIRM
More Costs Absorbed & Passed On
More Regional Cooperation
Savings from Reduced Raw Materials
Recycling & Re-use of Materials
Reduction of Offending Materials

Chapter 6 Summary and Conclusions

The Ecosystem of Machines Information System (EMIS) is a computer assisted planning tool used to identify alternative strategies for pollution abatement. It systematically scans a data base of industries and processes which can make possible matches of producers and consumers for the purpose of recovery and re-use, substitution of polluting processes with cleaner ones, and shared and ecologically cycled waste disposal. It augments the point source restrictions which are the basis of current abatement by relating specific polluters to a more general framework of alternatives. The ideal is to match as many polluters as possible with firms which can use the pollutants as resources. EMIS acts as a finder of producers and consumers of materials in the hope of encouraging less costly alternatives than simple collection and dumping. These latter alternatives dominate present strategy and will ultimately hit limits through the scarcity of natural resources and by curbing economic growth in order to limit the point sources of pollution. EMIS points to alternatives and provides a technique and tool for determining these alternatives which market phenomena alone will not signal.

Conclusions

The designers of EMIS believe that no further study is needed. This study has pointed the way to building the information system and the next step is an operating system. Design completions can be part of operational tasks. Part of the necessary data has been identified in Chapter Two and the availability of data is improving as the effort toward abatement moves forward. EMIS can help set guidelines for some of that future data collection because data availability and implementable strategies are highly interactive. By establishing the data needed to evaluate and implement alternative strategies, an operating EMIS could help avoid collecting non-applicable data. It would be useful as a next step to build a pilot data base for a limited number of industries and pollutants. These data could exercise a manual analytic routine and EMIS could be examined in the context of its operations.

EMIS software should then be built, for it generates alternatives which will become attractive as the limits of present strategy become more evident. The alternatives of shared resources and shared costs identified by the EMIS matching process can give a specific delineation of the feasibility of alternative strategies by identifying the number of scanned cells having empirical content. Ambitious ideas like a closed industrial cycle will be limited to practical application and some sense of proportion for each strategy can be identified by region and by national factors. The opportunities of EMIS have been stressed in this report, but the fact that it also gives feedback on the limits of alternative strategies should not be discounted as an aid to government policy formulation or corporate planners seeking specific programs of action.

When EMIS is built, it should have highly flexible design so that the users can include the planning function as well as an action orientation. While there might be different detailed levels for investigation in the two forms, the basic idea is of use to both types of clients. Government clients can use it for generating and evaluating the empirical scope of a strategy under investigation. Enforcement agencies can determine ways of alleviating hardship. Industry can use it to find specific markets for residues and sources of reclaimed materials. This will affect locational criteria especially and lead to a more efficient use of industrial and land resources. Even the definition of a pollution abatement region can be drawn by industrial communications rather than geography.

Present abatement procedures, both regional and point source, do not take full advantage of the opportunity for cost reduction of clean-up programs by sharing costs of materials and their disposal. As has been indicated, they also will fail when the number of sources of pollution expand as the economy expands. Even with an order of magnitude change in technical collection and disposal efficiency, the problem of conservation of resources is unchanged. Furthermore, the high cost of that technology could be better invested in growth rather than in the economically less productive investment in cleaning equipment. By relating the overview of the industrial network to the point source restrictions, an array of alternatives is generated and a systematic technique for investigating these alternatives is needed.

The creation of the Environmental Protection Agency will facilitate the strategies suggested in this report. The breakdown of waste classifications by air, water and solids has discouraged thinking about re-use of materials. Bringing existing agencies together should affect both the way data is collected and the strategies open to the Federal government. EMIS can prevent the opportunity of EPA from being missed by calling attention to the relations between data and strategy and by putting forward concrete examples where alternatives encourage economic growth while discouraging pollution.